U.S. Department
of Transportation
**Federal Highway
Administration**

Analysis of PMS Data for Engineering Applications

PARTICIPANT'S WORKBOOK

NHI Course No. 131105

PREPARED BY:

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NATIONAL HIGHWAY INSTITUTE
Training Solutions for Transportation Excellence

National Highway Institute

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MODULE 1

Overview of Engineering Applications of PMS

Module 1
Overview of Engineering Applications of PMS
Instructional Time: 60 minutes

Participant Questions

1. Identify issues and concerns amongst participants about subjects and concepts raised during the overview.

2. Summarize these on a flip-over chart and hang this at a visible location where they can be referred to during the balance of the course.

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Module 1
Overview of Course
"Analysis of PMS Data for Engineering Applications"

Federal Highway Administration

Prepared By TRDI

(Texas Research & Development Inc.)

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Course Instructors

- Instructor 1
- Instructor 2
- Instructor 3

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Course Objectives

- Provide overview of PMS and related systems, techniques and databases
- Discuss results of engineering analysis carried out by several state DOTs, and demonstrate benefits of these studies
- Stimulate agencies to enhance their PMS data base and use PMS data in range of engineering applications

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Module 1 - Objectives

- Review Basic Concepts of Pavement Management Systems
- Outline Principles of Engineering Analysis
- Quantify Benefits of PMS

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How Does PMS Relate To Your Engineering Activities

- Pavement (overlay) design analysis
- Materials & construction methods
- Preventive maintenance
- Pavement preservation strategies
- Pavement maintenance management

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Course Modules

Day 1	Day 2
1. Overview	7. Materials - Construction
2. Database needs	8. Preventive maintenance
3. Superpave monitoring	9. Preservation strategies
4. Performance modeling	10. Maintenance effects
5a. Workshop 1	5b. Workshop 2
6. Design analysis	11. Evaluation & Closing

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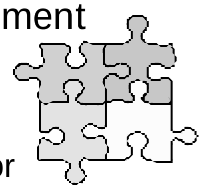
Pavement Management



Is a coordinated systematic process for carrying out all activities related to providing pavements

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Pavement Management System

Rational procedures that provide optimum pavement strategies based on predicted pavement performance incorporating feedback regarding the various attributes, criteria, and constraints involved.

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Overview of PMS & Related Issues

- Network & project levels
- Database issues
- Performance & design model applications
- Pavement preservation and rehabilitation
- Pavement maintenance systems

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PMS Conceived as Framework to Design for Local Environment

- Objectives of Texas study in 1960's:
  - Develop descriptions of material properties
  - Develop measuring properties for pavement design and evaluation
  - Develop pavement design methods using measured material properties, for all locations, environments and traffic loads.
- Goal: formulate overall pavement problem in broad conceptual and theoretical terms

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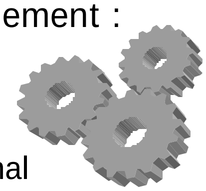
General Structure of Systematic Pavement Management :



Coordinated modules at several organizational levels accessing a common database

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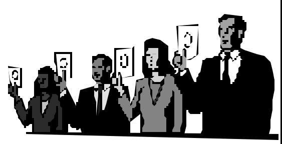
Benefits of PMS

- Consistently good decisions
- Evaluate funding effects
- Longer pavement life
- Extend M&R funds
- Improve efficiency
- Permit objectivity



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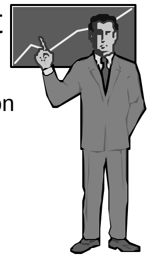
Let’s Review Pavement Management



- Formalization of pavement decision making
- Entire process to provide quality pavements
- Strong emphasis on economics
- Involves all associated groups
  - Planning, Design, Constr, Maintenance, Materials, Field Groups.
- Uses advanced tools and analysis techniques

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What is Pavement Management Software

A set of <u>Tools</u> to <u>Assist</u> Decision-makers in <u>Preserving</u> a <u>Pavement</u> Network

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PMS Components

- Pavement condition analysis
- M&R needs analysis
- Optimize budget allocations
- Prioritize M&R projects
- Select best life cycle strategies
- Design pavement structure
- Program/Track routine maintenance

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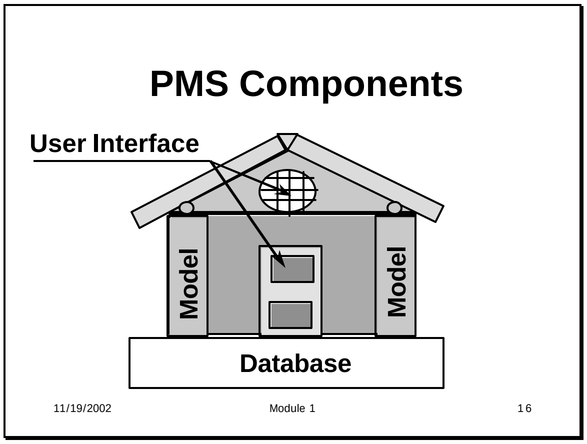

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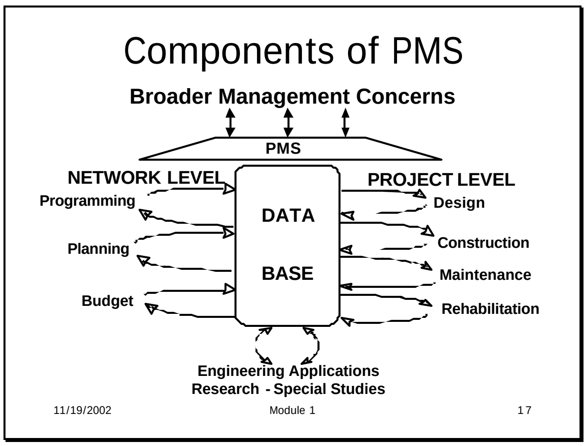

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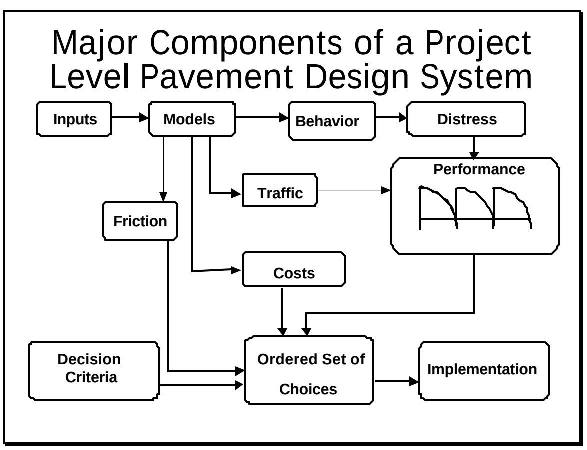

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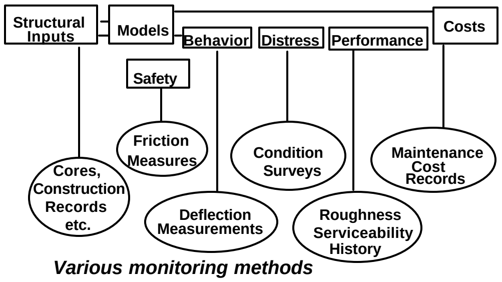
Types of Evaluation Information



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Functions of Pavement Evaluation in PMS

- Check design predictions
- Schedule rehabilitation
- Improve design models
- Improve construction and maintenance
- Updating network programs

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A quote which properly defines a PMS database by Aaron J. Ihde:

“The primary factor in bringing about scientific discovery is not necessity or individual genius, but the relentless pressure of accumulating knowledge”.

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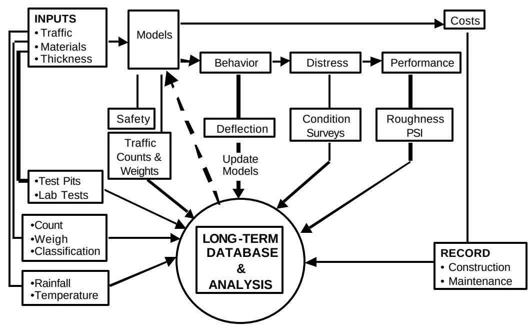

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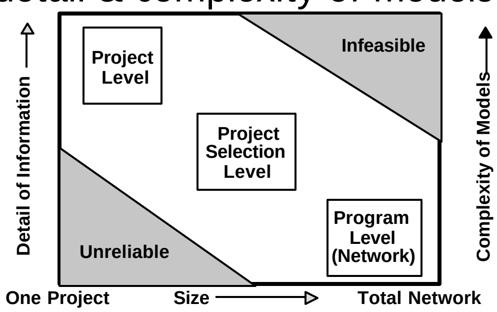
Three level PMS - Information detail & complexity of models



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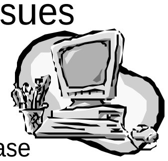
Technical User Issues



- Database design/operation
- Data acquisition methods
- Ensuring adequacy of database
- Predictive Models
- Performance Criteria
- Models for priority analysis and network optimization
- Verification of models

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Essential Requirements of PMS

- Easily updated/modified as new information and models become available
- Considers alternative strategies
- Identifies optimum strategy
- Bases decisions on rational procedures with quantified attributes, criteria, constraints
- Uses feedback information regarding the consequences of decisions

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Summary of PMS

- Network and project level
- Several major subsystems
- Performance database for model development
- Proper information flows
- Pavement evaluation

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Purpose of PMS Engineering Analysis

The use of pavement management data to evaluate and improve structural designs, materials, mix designs, construction, preservation strategies, rehabilitation, and preventive maintenance of pavements.

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Engineering Analysis Essential part of PMS

- Pavements are engineered structures, therefore engineering analysis:
  - Improves pavement performance
  - Can be used for network or individual problems
  - Is essential for feedback purposes
  - Affects future activities - design, construction maintenance, standards, and specifications
- Involves both project and network level data

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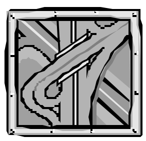
Sources of Engineering Data other than from PMS database



- Research data files
- Construction records
- Material test records
- Additional field evaluations
- Project plans
- Additional structural evaluation and/or materials testing
- Expert opinion and forensics
- Maintenance Management Systems

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Engineering Application Examples from following State DOT's

- Arizona
- California
- Florida
- Georgia
- Kansas
- Maryland
- Michigan
- Montana
- Pennsylvania
- Texas
- Washington
- Wisconsin

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Arizona State DOT's Engineering Analysis Elements

- Module 1:
  - Overview of ADOT PMS
  - Methodology to show benefits of using a PMS
- Module 3:
  - Superpave performance monitoring
- Module 6:
  - Evaluating overlay design techniques
- Module 7:
  - Effectiveness of various overlays and surface treatments

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ADOT's PMS Overview

- Pavement network 7600 center line miles
- Condition data collected annually at each milepoint
- Centralized Pavement Management Organization with 11 staff
- Budgets increased from $35 million in '80 to over $100 million now

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Quantified Benefits of a PMS

- Study for Arizona DOT in 1998 by TRDI
- ADOT's PMS was initiated in 1980
- Need to evaluate impact of PMS on:
  - pavement performance
  - pavement life
  - selection of materials
- Use of PMS database to quantify effects

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Creating The Database

- Historical Roughness data split as follows:
  - Data that reflect **Pre-PMS** experience from years 1981 - 1983
  - Data that reflect **Full-PMS** experience from years 1993 - 1995. (For later years project files not complete).
- Data evaluated in Visual Modeler.
- Each period contains about 20,000 records.

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Analyses Were Run For:

1. All pavement types in the state
2. All interstate pavements only
3. All rigid pavements only
4. All interstate rigid pavements only
5. All asphalt pavements only
6. All interstate asphalt pavements only

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Five Performance Indicators

1. Roughness
2. Cracking
3. Patching
4. Friction
5. Flushing

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Results

- Roughness by far the best indicator of performance and shows the best correlation for data set.
- Cracking shows stable relationships, but not as robust as for roughness

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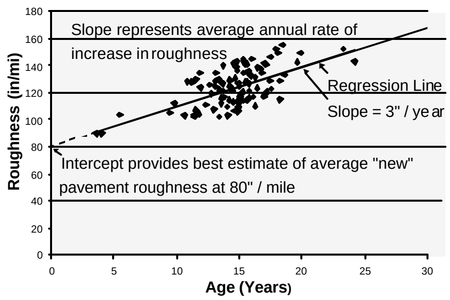
Quantify With Visual Modeler



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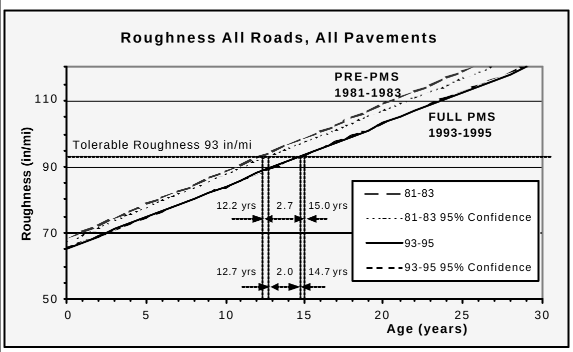
PMS Results in Longer Life



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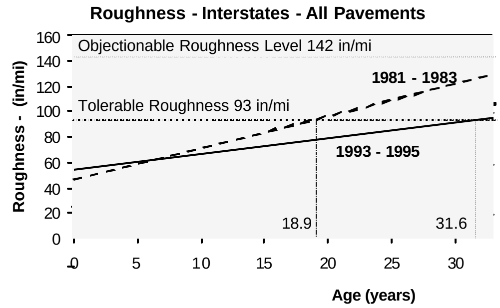
Example for Interstates only



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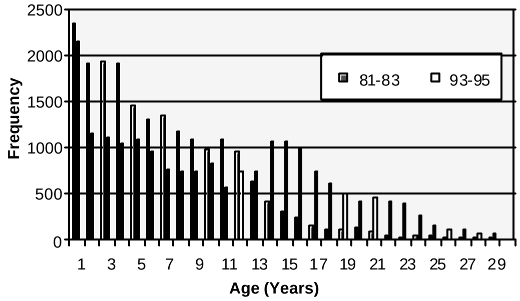
Age Distribution
All Roads, All Pavements



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ADOT's Budgets 1981-1996 (millions)

Fiscal Year	Preservation		New Re-construction		Pavements Total	
	$$	Miles	$$	Miles	$$	Miles
1981	43	400	115	43	158	443
1982	28	278	133	45	161	423
1983	39	386	93	20	132	406
1984	56	544	183	25	239	569
1985	48	280	92	27	140	307
1986	48	290	145	24	193	314
1987	47	275	141	52	188	327
1988	67	296	150	90	217	386
1989	56	269	205	67	261	336
1990	78	371	221	92	299	463
1991	70	250	181	71	251	321
1992	88	308	74	35	162	343
1993	77	275	56	17	133	292
1994	60	209	69	22	129	231
1995	62	251	120	40	182	291
1996	68	222	222	53	290	275
TOTAL	**935**	**4,904**	**2,200**	**723**	**3,135**	**5,727**

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Quantification of Benefits

- Improved Pavements with longer life:
- Total Budget for yrs 81-96: $3,135 million
- Average increase in life 2.0 yrs or 13.5%
- Minimum increase in life 1.3 yrs or 8.6%
- Average corresponding benefit over 16 years of $423 with minimum of $270 million at 95% confidence.

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ADOT PMS Development Costs

Consulting Services 1979 $300K
Temporary Staff 1979 – 1983 $400K

Total $700K

Average for 16 years = $43,700

Amortized 25 years @4% = $50,000

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ADOT PMS Operating Costs Example

	1981	1996
Labor	$275K	$370K
Travel	$30K	$30K
Annual capital cost for equipment	$65K	$65K
Equipment Operat.	$60K	$65K
Annual Total	$430K	$525K

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ADOT Total PMS Costs

	1981	1996
DEVELOPMENT	44,000	44,000
OPERATING	430,000	525,000
TOTAL	474,000	569,000

TOTAL FOR 16 YEARS = $8,340,000

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ADOT's PMS Total Benefits/Costs

Total PMS costs $8.3 Million over 16 yrs. Benefits at minimum confidence level $270 Million, at average level $423 Million.

Minimum at 8.6% increase in life:
Benefit/Cost Ratio = $\frac{\$270 \text{ Million}}{\$8.3 \text{ Million}}$ = 33 to 1

Average at 13.5% increase in life
Benefit/Cost Ratio = $\frac{\$423 \text{ Million}}{\$8.3 \text{ Million}}$ = 51 to 1

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Total Benefits/Costs Sensitivity Including User Costs

- Assume minimum benefits (95%) of $270 million with 33:1 benefit cost ratio (BCR)
- World Bank: User benefits are 4 - 10 x cost of road expenditures,
- Benefits to Arizona citizens over 16 yrs would be at least $ 1 billion, with BCR of more than 100:1

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Summary of PMS Benefits

- Many “general” benefits, such as improved communications, better decision taking, asset management, etc are present in PMS but difficult to quantify.
- With well maintained comprehensive database, benefits can indeed be defined in number of ways, and reliably quantified.
- As shown in Arizona, they are sizeable.

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Module 1 -Objectives

- Can you give basic concepts of Pavement Management Systems?
- Outline principles of Engineering Analysis?
- Summarize benefits of PMS?

MODULE 2

Database Needs & Elements

Module 2
Database Needs & Elements
Instructional Time: 35 minutes

Participant Questions

1. What is your involvement with a database (central or in your own group)?
2. Are you providing data or using them?
3. Do you have easy access to data that are important for your job?
4. What are the major concerns about databases in your agency?

Slide 1

Module 2
Database Needs and Elements for Engineering Applications

Slide 2

Module 2 - Objectives

- Identify data needs for Engineering Applications
- Identify importance of electronic databases
- Clarify data organization needs

Slide 3

Scope for Database Needs & Elements

- Network & Project Level quality data
- Additional data for engineering analysis
- Data mining
- Data accuracy, reliability, & applicability
- Integration and centralization of data
- Statistical Analyses

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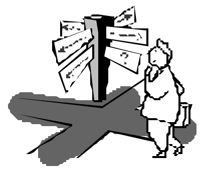
Classes of Data Required

- Section Description
- Performance Data
- Historic Data
- Traffic Data
- Policy Data
- Geometry Data
- Environment Data
- Cost Data



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Data as Central Feature

Planning & Programming

Project Selection

Design

Section Description
Performance related
Historic related
Policy related
Geometry related
Environment related
Cost related

Construction

Maintenance

Research

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Data for Performance Related Parameters
(at Network & Project Level)

- Roughness - serviceability/comfort
- Surface Distress - preservation
- Deflection - structural adequacy
- Material Properties - durability/economy
- Surface Friction - safety

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Example of Use of Performance Related Data: Roughness

Network Level

a) Describe present status

b) Predict future status (deterioration curves of roughness vs. time or loads)

c) Basis for priority analysis and programming

Project Level

a) Quality assurance (as-built quality of new surface)

b) Create deterioration curves

c) Estimate overlay quantities

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Example of Use of Performance Related Data: Deflection

Network Level

a) Describe present status
b) Predict future status
c) Identify structural inadequacies
d) Priority programming of rehabilitation
e) Determine seasonal load restrictions

Project Level

a) Input to overlay design
b) Determine structural adequacy
c) Estimate remaining service life
d) Estimate required load restrictions

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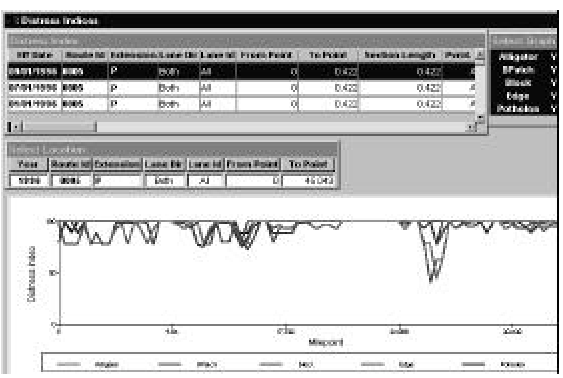
Montana Condition Review Window



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Data for Historic Related Parameters
(at Network & Project Levels)

- Maintenance - Effectiveness
- Construction - QA/QC, Acceptance testing, as-built records
- Traffic - growth, composition, controls
- Accidents - High risk sites, countermeasures

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Example of Use of Historic Related Data: Maintenance History

Network Level

a) Maintenance Programming

b) Evaluate maintenance effectiveness

c) Determine cost-effectiveness of alternate designs and treatments

Project Level

a) Identify problem sections

b) Estimate maintenance effectiveness

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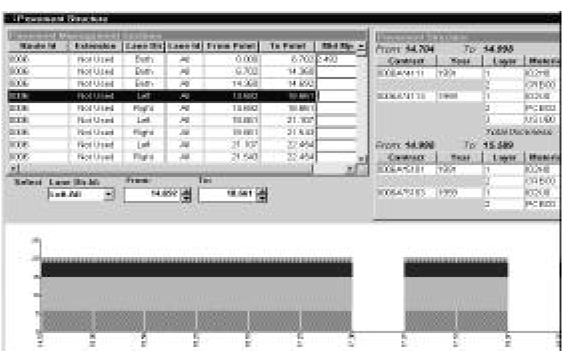
PennDOT Structural History Review



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Importance of Construction & Maintenance History Data

- Must have as-built data for
  - Performance modeling
  - Assessing construction quality
- Maintenance history
  - Affects performance
  - Evaluate effectiveness

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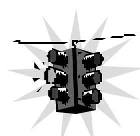
Consistency in Pavement Evaluation Data



- Objective evaluations
  - With calibrated instruments
  - Or well-trained evaluators
  - Explicit instruction on survey methods
- Consistency across time and space

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Standards for Network Level PMS Data Collection

- Data consistency nationwide desirable
- FHWA research project in 1996
- Standards for collection of cracking, rutting, faulting and roughness
- Examined or adopted as AASHTO Provisional Standards
- Many benefits for PMS Engineering Analysis

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Pavement Management Sections

- Permanent location reference
- Cross referenced for all other systems and uses
- Dynamic segmentation
- Data aggregation

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Data Integration & Centralization

- Electronic Data essential
- Integrated Systems
- Integration Methods and Tools
- Analysis of Database
- Statistical Analyses required

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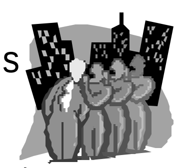
Integrated Systems



- Shared data
- Location referencing standards
- Traffic information
- Condition status
- Work programs
- Maintenance needs and effects

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Integration Methods & Tools

- Integrated Data
  - Shared data across organization
  - Multiple location cross-referencing
- Integrated Data base(s)
  - Centralized data base
  - Distributed (replicated) data bases

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Analysis of Database / Data Mining

- Supplement with additional data
- Organize and cleanse PMS data, provide in format ready to use
- Evaluate suitability of data base
- Statistical Analysis

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Statistical Analyses

- Deterioration/road performance curves
  - Statistical - Regression Analysis
    - Least squares, Linear regression, Non-linear models
  - Probabilistic - Transition Probability Matrices
    - Markov transition process
- General data - aggregate results
  - Percentiles, Mean, Mode, Median, Variance, ANOVA, F-test, Standard deviation, Coefficient of variation, R-square, etc.

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Database Summary

- Databases for engineering analysis
- Sectioning and location referencing
- Data classes and elements
- Integrated / shared databases
- Database as central focus of PMS
- Historical data for performance analysis
- Mining and analysis of database

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Module 2 - Objectives

- Please identify data needed for Engineering Applications
- How important are electronic databases?
- What data organization is needed?

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MODULE 3

Superpave Performance Monitoring

Module 3
Superpave Performance Monitoring
Instructional Time: 50 minutes

Participant Questions

1. Let's get some feedback from somebody in construction, somebody in the lab/materials, somebody in design, and somebody with PMS as to their potential contribution to make performance monitoring easier.

2. Can you collect most of the needed data?

Slide 1

Module 3
Using PMS Data to Monitor Performance of Superpave

Study for FHWA by TRDI in 2000/2001 with input from:
- Maryland SHA
- Florida DOT
- Indiana DOT
- Arizona DOT
- Washington State DOT
- The University of Washington

Slide 2

Module 3 - Objectives

- Illustrate how to use PMS to evaluate performance of new materials like Superpave and to validate new design concepts
- Evaluate experience of 5 states in collecting PMS-related data for analysis
- Outline support needed for state DOTs to do a proper analysis with compatibility of data among states
- Formulate a multi-state study

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Phase 1 – Collecting Information & Recommendations

from Maryland SHA, Florida DOT, Indiana DOT, Arizona DOT and Washington State DOT

Phase 2 – Pathfinder Study

in Maryland SHA with help of the University of Washington

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Phase 1 - Collecting Information

In each state information obtained about:

- Details of their PMS
- Data collection methods used
- Network pavement performance monitoring
- Pavement evaluation techniques
- Details of Superpave projects:
  - List with projects and size and location
  - Performance data for these projects
  - Materials & construction data

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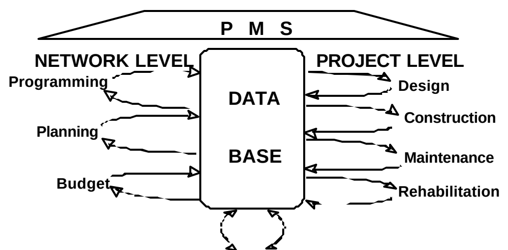
Components of Ideal PMS



Engineering Applications
Research - Special Studies
i.e. Analysis of Superpave

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Purpose of PMS Engineering Analysis

Use of PMS data to evaluate & improve structural designs (e.g. AASHTO 2002), mix designs, materials (e.g. Superpave), construction, preservation strategies, rehabilitation, & preventive maintenance of pavements.

But: PMS may not have detailed data!

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Sources of Engineering Data other than from PMS database

- Research data files,
- Construction records,
- Mix design and testing records,
- Additional field evaluations,
- Project plans,
- Pavement design data,
- Additional structural evaluation and/or materials testing,
- Maintenance Management Systems.

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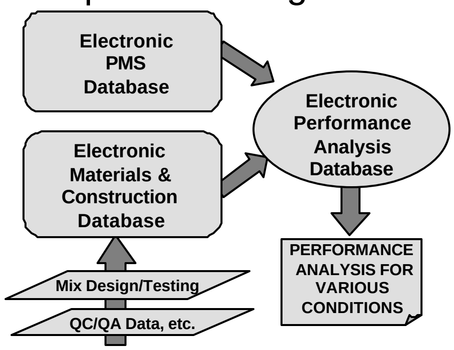
Concept for Linking Databases



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Current Limitations (1 of 2)

- In most cases materials, construction, and maintenance data not now tied to PMS data.
- Most agencies store materials and construction data in flat files, so transfer and analysis of data difficult.
- Not all relevant data recorded (e.g. in-place thickness often missing).
- Linking materials and construction data to an exact location normally not possible.

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Current Limitations (2 of 2)

- Performance data often averaged over a mile. Distress often sampled over short distances, e.g. milepost only. Normally only one lane measured.
- Therefore, difficult to link performance data to materials and construction data.
- Maintenance activities, if not properly recorded and referenced, could distort analysis.
- DOTs need time to implement new approach in existing structures.

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Desirable Components of Electronic PMS Database

- **Common referencing needed with Project Number, exact Location & Date**
- Climate and Traffic (ESAL and ADT) Data
- Age of original pavement & last rehab date
- Details of existing pavement structure
- Performance Data for various distresses linked to exact location (mile post or GPS, Lane and Direction).

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Desirable Components of Electronic Materials and Construction Database

- **Common referencing needed with Project Number, exact Location & Date**
- Mix data, as designed and in-place
- Layer thickness, designed and actual
- Other materials & construction details
- Effects of maintenance activities
- Batch/lot numbers linked to location.

Slide 13

Electronic Performance Analysis Database - Created by Linking

- **Common referencing needed with Project Number, exact Location & Date**
- Essential materials & construction data linked to performance data through common referencing
- Possible to study effects on performance of materials, construction techniques, traffic loads, climate, thickness design (AASHTO 2002), etc.

Slide 14

Network Analysis Possibilities

1. Assemble database for adequate number of sections,
2. The more sections the better - large sample statistics very powerful,
3. Several States can combine data if good coordination at national level provided,
4. Effects of variables in database can be evaluated and analyzed,
5. Early implementation provides impetus to enter data early – Data backlog does not “build-up”.

Slide 15

Project Analysis Possibilities

- Assemble Database for lots or batches,
- The more lots the better - large sample statistics very powerful (lots across projects with similar characteristics can combine data),
- Effects of variables in database can be evaluated and analyzed, such as:
  - Variability in material properties,
  - Susceptibility of materials or techniques to adverse conditions,
  - Assessing best compaction techniques for certain materials, etc.

Slide 16

Phase 2 Pathfinder Study

Pathfinder study in Maryland to:

- Establish what data are required to link performance to materials and construction data,
- Collect all relevant data and put these in electronic format, and
- Load these into web-based system for storage, linking, evaluation and reporting.

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Slide 17

PMS in Maryland

- SHA highway network - 16,362 lane miles
- Approximately 10,000 directional miles monitored annually in outside lanes with ARAN vehicle for IRI, rutting and cracking.
- Reporting of cracking numbers still awaits interpretation of video images.
- Friction measured every 0.1 mile with ASTM skid tester.
- Superpave applied since 1995.

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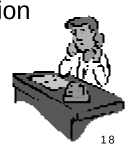
Slide 18

Elements of Pathfinder Study

- Maryland SHA agreed to provide PMS, materials and construction data in electronic format,
- University of Washington offered to put the MD data in their newly developed web based evaluation system,
- TRDI coordinated.



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Slide 19

Types of Data Needed for Analysis as Proposed by MDSHA

QC/QA Data	Mix Design Data
28 fields: Electronic: 8 Paper: 16 Not available: 4	16 fields: Electronic: 9 Paper: 6 Not available: 1
Pavement Design Data	**PMS Data**
11 fields: Electronic: 0 Paper: 10 Not available: 1	16 fields: Electronic: 9 Paper: 4 Not available: 3

Slide 20

Difficulty of Data Retrieval in MD

SUBJECT	SOURCE FILES	DIFFICULTY
PMS data	PMS data file	easy
Mix design	QC/QA database	easy
Mix QC and QA	QC/QA database	easy
Inventory Information	Project & Design	Medium
Density QC and QA	QC/QA database	Medium
Pavement Design Recommend.	Pavement design	Medium
Pre-overlay condition	Pavement design	Medium
Ride QC and QA	Construction	Hard
Daily & Project Paving	Construction	Hard
Binder & Aggregate tests	Various files	Unable

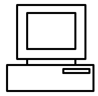
Slide 21

Website System with Superpave Data

- Developed by University of Washington, Dept. of Civil & Environmental Eng., in cooperation with WSDOT and NCAT,
- Currently used for data from DOTs of Washington, Missouri, Texas & Maryland,
- Acts as data warehouse, with sorting, viewing, linking, analysis and reporting capabilities.

Slide 22

Advantages of Website System

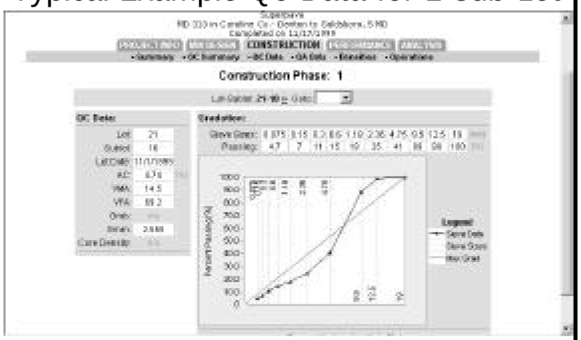


- Graphing and Summary functions
- Data export to Excel available
- Handles visual images (e.g. infrared)
- Flexible data presentation for each state
- Static GIS map location for each project
- Data immediately available to all users
- Easy to use data across projects or states

11/15/2002 Module 3 22

Slide 23

Typical Example QC Data for 1 Sub-Lot



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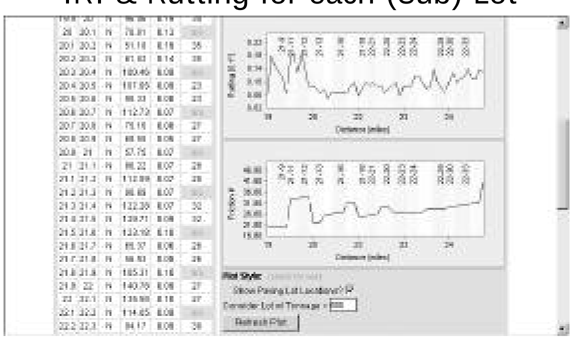
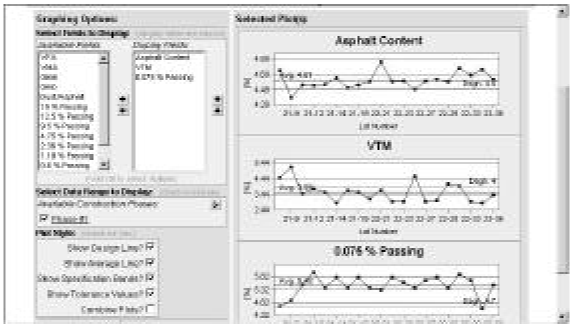
Slide 24

Typical Example IRI & Rutting for each (Sub) Lot



Slide 25

Typical Example Graphing Options for Volumetrics



Slide 26

Possible Evaluations At Network Level

- Binder content vs rutting,
- Fines (passing P200) vs rutting,
- IRI of several projects by year,
- Rutting of several projects by year,
- IRI vs use of Material Transfer Vehicle,
- IRI vs night/day paving,
- IRI vs surface preparation.

Slide 27

Possible Evaluations At Project Level

- IRI by year,
- Rutting by year,
- IRI vs distance/lots,
- Rutting vs distance/lots,
- IRI vs use of Material Transfer Vehicle,
- IRI vs night or day paving,
- IRI vs surface preparation.

Slide 28

Advantages of Concept for a DOT

- Existing pavement network used as road test:
  - Evaluate different materials, techniques, design concepts, etc
  - Produce more accurate pavement prediction models
- Pavement preservation done more accurately
- Data entered only once, and data warehouse allows easy storage, retrieval, linking, analysis and reporting.

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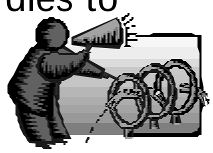
Organizational Hurdles to overcome



- Resistance to change
- Lack of funds
- Fear for loss of control at group levels in DOTs
- Problems to standardize performance indices
- Fear that data are misused or that confidential data show up outside DOT
- IT Dept. might resist shift from Mainframes to Servers.

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Slide 30

Technical Hurdles to overcome

- Linking performance data to materials & construction data difficult because:
  - Performance data often averaged over a mile,
  - Distress often sampled over short distance only at each mile point,
  - Mostly only one lane measured.
- Maintenance activities, if not properly recorded and referenced, could distort analysis

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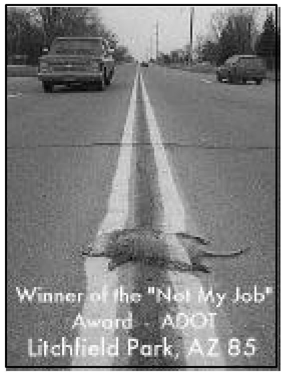
Slide 31

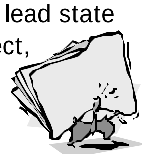
Another Hurdle to overcome



Slide 32

Specific Actions - Superpave

- States need help to implement this concept
- Needed: a champion for the multi-state project, i.e. AASHTO Committee, FHWA representative, State representative,
- A State willing to actively be the lead state in a Superpave Multi-state Project,
- Funding,
- Support by FHWA and AASHTO.



Slide 33

Specific Actions – AASHTO 2002

- Recognizing need to evaluate 2002 Pavement Design Guide – New concept, not implemented or proven,
- Needed: early planning to set up outline of monitoring study before large usage develops – get ahead of game,
- A State willing to actively be lead state to promote Project,
- Funding,
- Support by FHWA and AASHTO.

Slide 34

Conclusion

Good PMS Data Can Be Used to Evaluate Materials and Techniques

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Module 3 - Objectives

- How can PMS be used in your agency to evaluate performance of Superpave?
- Does your agency collect most of the data needed?
- Let's hear the views of somebody in
  - Pavement management
  - Materials
  - Construction
  - Maintenance

MODULE 4

Performance & Pavement Modeling

Module 4

Performance & Pavement Modeling
Instructional Time: 55 minutes

Participant Questions

1. How is your agency handling performance modeling?
2. Do you see possibilities for a better use of these techniques?
3. Are your prediction models generic, or tailored to your conditions?

Slide 1

Module 4: Performance and Pavement Modeling

- Development of performance models from network data
- Pavement performance data and models used by PennDOT
- Pavement performance model curves used by WSDOT

11/15/2002 Module 4 P & P Modeling 1

Slide 2

Module 4 - Objectives

- Identify importance of performance models in network level pavement management
- Assess work on performance and pavement modeling
- Formulate the concepts
- Stimulate interest in performance modeling applications

11/15/2002 Module 4 2

Slide 3

Pavement Performance Models

Obtaining good models for performance versus age or traffic loads is essential

- Performance generalized to mean deterioration or damage over time or traffic
- Pavement performance analysis is primary engineering application
- Includes analysis of effects and interaction of several parameters, mostly present in PMS database

11/15/2002 Module 4 3

Slide 4

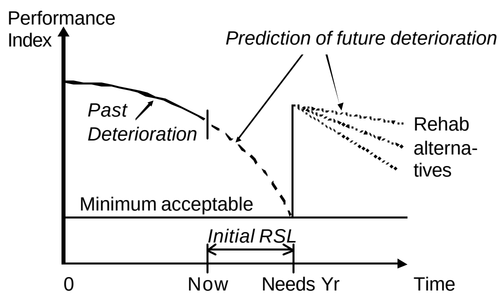
Requirements for Performance Modeling

- Adequate database
- Inclusion of significant variables affecting deterioration
- Careful selection of functional form of model to represent physical real-world situation
- Criteria to assess precision of model

11/15/2002 Module 4 4

Slide 5

Application of Deterioration Models



11/15/2002 Module 4 5

Slide 6

Basic Types of Prediction Models

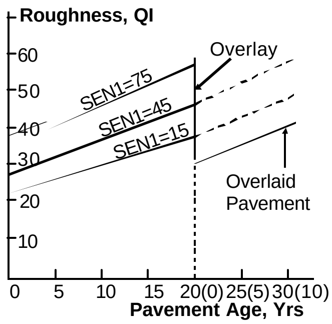
- Purely mechanistic (Not Available)
- Mechanistic - Empirical
- Regression
- Subjective (Transition process)

11/15/2002 Module 4 6

Slide 7

Example of Mechanical - Empirical Roughness Model

Log(QI)= f {AGE, N, ST, RH, SEN1,}
Where,
QI = roughness, counts/km
Age = pavmnt age, Yrs
ST = surface type
RH = rehab. indicator
SEN1= strain energy at bottom of asphalt layer (10^{-4} kgf cm)
N = CESAL's

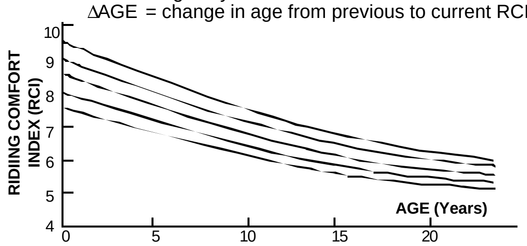


Slide 8

RCI Regression Model

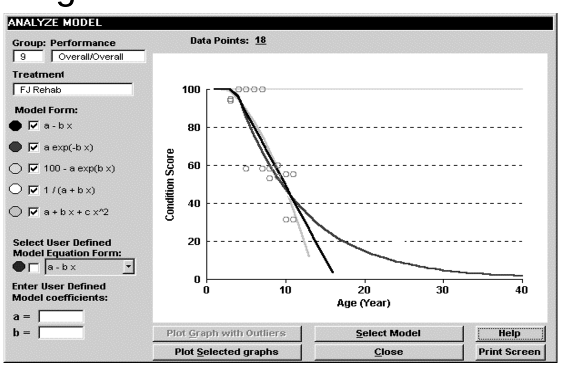
RCI = f { RCI_B, AGE, ΔAGE }

RCI = Riding Comfort Index (0-10) at any AGE
RCI_B = previous RCI
AGE = age in years
ΔAGE = change in age from previous to current RCI



Slide 9

Regression with Visual Modeler



Slide 10

Transition Probability Matrix for Markov Model

Initial Condition State	Future Condition State				
	Very Good	Good	Fair	Poor	Very Poor
Very Good	0.90	0.10			
Good		0.93	0.07		
Fair			0.88	0.12	
Poor				0.85	0.15
Very Poor					1.00

Slide 11

Other Factors that Affect the Transition Matrix

- Pavement type
- Pavement thickness
- Traffic volumes and loads
- Subgrade type or strength
- Environmental and regional effects

Slide 12

Use of Performance and Design Models for Engineering Analyses

- Models create possibility to predict performance over time in measurable terms
- In examples in remainder of course performance & design models are featured in several ways.

Slide 13

PennDOT’s Engineering Analysis Elements

- Module 4:
  – Overview of PennDOT PMS
  – Pavement performance data & modeling
- Module 9:
  – Techniques for selecting pavement rehabilitation strategies

11/15/2002 Module 4 13

Slide 14

PennDOT’s Roadway Management System (RMS)

- STAMPP - PMS
- BMS - Bridge
- PRMS - Project
- MORIS - Maintenance
- ARS - Accident
- FMIS - Financial
- CMS - Construction
- CAMS - Construction & materials
- GIS - Geographic

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Slide 15

STAMPP

Systematic Technique to Analyze and Manage Pennsylvania's Pavements

11/15/2002 Module 4 15

Slide 16

STAMPP Contains

- Comprehensive pavement distress data
- 11 Districts
- Segments nominally 1/2 mile long
- Data for all lanes
- Separate survey results for asphalt roads, and jointed, and continuously reinforced concrete roads

Slide 17

Outputs of RMS & STAMPP

- Annual work plan
- Graphical maps using GIS
- Annual state-of-the-Interstate
- Input for transportation improvement plan (TIP)
- Highway Performance Monitoring System (HPMS) reports

Slide 18

Distress Data Collection

- Annual survey 26,000 center line miles, all NHS and half of other roads, May - Sept.
- IRI with S-Dakota style profilers
- Up to 1996 - manual distress survey by 200 college students with quality audits
- Since 1997 - contracting for automated data collection, reasons:
  - Lower cost, particularly for training and travel
  - Exposure of raters to traffic
  - Variation in data between teams

Slide 19

Distress Scores

- Distress/condition measures are converted into distress scores with 0 -100 scale
- Distress scores calculated based on type of distress using either a distress converter or a maximum allowable extent algorithm
- Then performance indexes are weighted combinations of selected distress scores

Slide 20

Combination of Distresses into Performance Indexes

- User selects distresses to include in each performance index (PI)
- Each included distress is weighted by user defined factor
- The weights are then used in multiplicative index calculation algorithm to produce final performance index scores

Slide 21

Combined Performance Indexes used by PennDOT

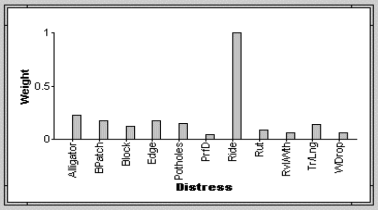
- Structural Index (STI)
- Surface Distress Index (SDI)
- Safety Index (SFI)
- Overall Pavement Index (OPI)
- Present Serviceability Index (PSI)

Slide 22

Definition of Overall PI

Performance Index # 10 Overall/Overall

Distress	Weight
Profile Distortion	0.04
Rutting	0.09
Ride	1
Raveling/Weathering	0.06
Block Cracking	0.12
Transverse/Long. Crac	0.14
Alligator Cracking	0.23
Edge Deterioration	0.17
Bituminous Patching	0.17
Potholes	0.15
Widening Dropoff	0.06



Slide 23

Pavement Performance Analysis

- Essential part of pavement management at all levels
- STAMPP does not use pavement performance modeling for forecasting
- Visual/PMS system handles performance analysis and forecasts of pavement condition

Slide 24

Modeling Process

PennDOT uses group based modeling:

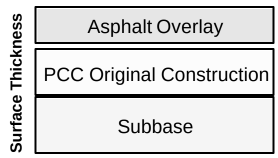
- Pavement network divided into homogeneous performance groups, based upon selected variables that affect pavement performance
- Examples of variables include functional class, traffic level, and pavement structural type
- Inside each group models are developed for each performance index

Slide 25

Road Structure Categories

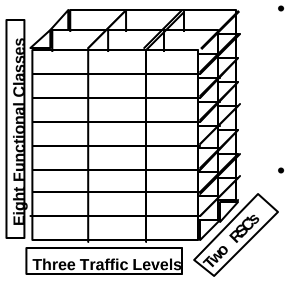
Road Structure Categories based upon:

- •Surface Material Type
- •Underlying Pavement Structure
- •Surface Thickness
- •Rehabilitation Type



Slide 26

Pavement Performance Groups



- Typical Performance Grouping uses
  - Traffic Level
  - Functional Class
  - Road Structure Category (RSC)
- One model is calculated for each group per Index, in this case 2*3*8=48 models

Slide 27

Model Building and Review

- Most modeling systems allow building two types of models:
  - Regression based - Deterministic
  - Transition probability based - Probabilistic
- Models are built for pavement groups using both linear and non linear equations

Slide 28

Deterministic Models based on Regression Equations

Four regression forms are available

#	*Model Form*	*Transformation*
1.	$y = a + bx$	None
2.	$y = 100 - a(e)^{bx}$	$y' = \ln(100 - y)$
3.	$y = a(e)^{-bx}$	$y' = \ln(y)$
4.	$y = 1 / (a + bx)$	$y' = 1 / y$

y = Performance Index
x = pavement age
a, b are regression coefficients

Slide 29

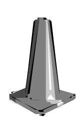
Probabilistic Models based on Transition Probabilities (Markov)

Transition probability matrices can be produced from the calculated regression equations with Visual Modeler

Slide 30

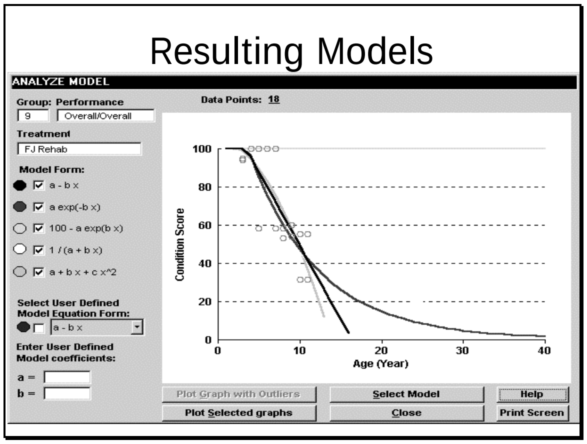
Modeling Example

- Model built for overall pavement index
- Road structure category: Pennsylvania FJ asphalt overlays of existing asphalt pavements
- The performance group is:
  - high traffic (AADT>3250)
  - NHS urban roadways



- 18 data points were available for analysis

Slide 31



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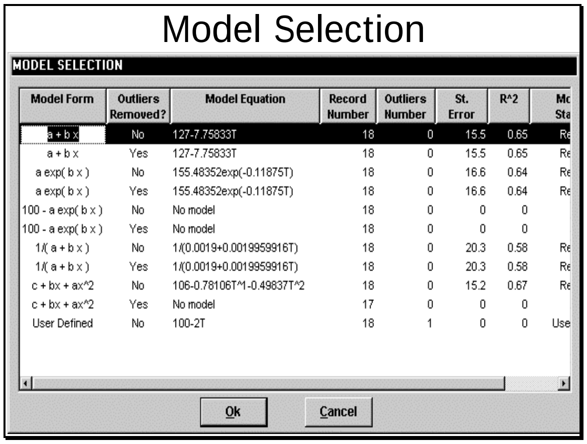
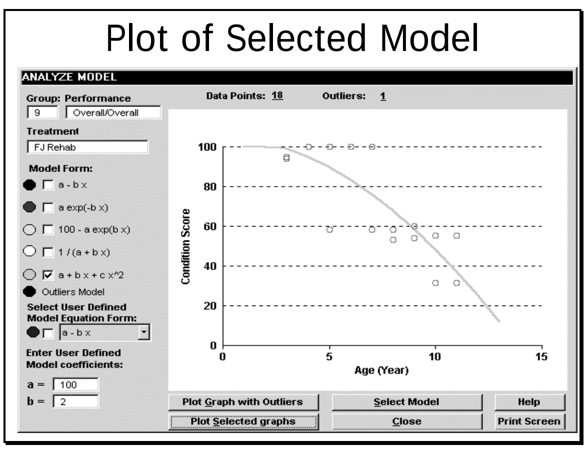

Model Selection

MODEL SELECTION

Model Form	Outliers Removed?	Model Equation	Record Number	Outliers Number	St. Error	R^2	Mo Sta
a + b x	No	127-7.75833T	18	0	15.5	0.65	Re
a + b x	Yes	127-7.75833T	18	0	15.5	0.65	Re
a exp(b x)	No	155.48352exp(-0.11875T)	18	0	16.6	0.64	Re
a exp(b x)	Yes	155.48352exp(-0.11875T)	18	0	16.6	0.64	Re
100 - a exp(b x)	No	No model	18	0	0	0	
100 - a exp(b x)	Yes	No model	18	0	0	0	
1/(a + b x)	No	1/(0.0019+0.0019959916T)	18	0	20.3	0.58	Re
1/(a + b x)	Yes	1/(0.0019+0.0019959916T)	18	0	20.3	0.58	Re
c + bx + ax^2	No	106-0.78106T^1-0.49837T^2	18	0	15.2	0.67	Re
c + bx + ax^2	Yes	No model	17	0	0	0	
User Defined	No	100-2T	18	1	0	0	Use

Ok Cancel

Slide 33



Slide 34

Washington State DOT's Engineering Analysis Elements

- Module 4:
  - Overview of WSDOT PMS
  - Pavement performance modeling
- Module 5:
  - SCOPER overlay design methods

11/15/2002 Module 4 34

Slide 35

Overview of WSPMS (part 1)

- Developed pavement condition survey program in mid '60's for setting priorities
- In late '70's, first WSPMS was developed
- Condition surveys every two years since '69 and every year since '88
- 1988 programs rewritten to fit mainframe file structures and to work in a local area network with PC's

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Slide 36

Overview of WSPMS (part 2)

- Problems with worst-first programming as budget estimates proved inaccurate
- In 1993 Legislature required Life Cycle Cost Analysis to prioritize rehabilitation projects
- Major update implemented to include Pavement Structural Condition Index and Project Scoping technique

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Slide 37

Overview of WSPMS (part 3)

- Eliminated worst-first programming
- PMS now predicts "due year" based on historic, condition & structural data and deterioration models
- Graphical displays provided in user-friendly environment
- 1995 update to Windows, conversion of files to ACCESS database

Slide 38

Components of WSPMS

- File building
  - Organizing several large data bases
- Interpreting program
  - Specific info on 3,200 sections statewide
- Project level analysis
  - Optimizing program for project selection
- Network level analysis
  - Ensuring best overall condition for fixed funding

Slide 39

Interpreting Program

- Develops project specific information
- Calculates rating scores, and following indexes:
  - Prior to 1993:
    - PCR – incl. rutting & structural information
  - Currently:
    - PSC - structural condition, based on cracking (fatigue cracking is main distress)
    - PRC - rutting condition
    - PPC - roughness (IRI)

Slide 40

Project Level Analysis

- In first PMS, project level optimization determined rehab strategy for each project
- Optimizing program ranked output in order of life cycle cost for array of rehabilitation strategies for each project
- Most projects identified early, so many overlays relatively thin
- New software makes project level info easily available to all pavement managers

Slide 41

Network Level Analysis

- Network analysis was always seen as natural extension of project selection
- Working toward network analysis to optimize project selection within each region for best overall pavement condition over time for fixed funding level
- “What if” scenarios will be run in future

Slide 42

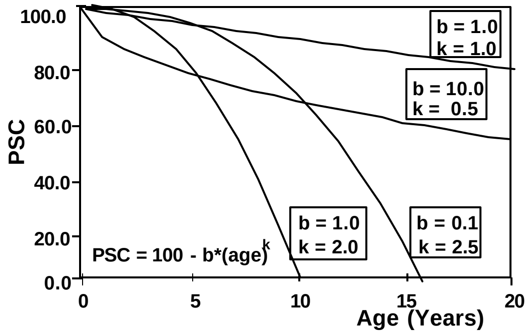
WSPMS Performance Equations

Performance equations are developed in three ways:

- Regression on data for pavement with known performance during several years
- Default equations covering overall performance of similar pavements in same region
- Equations based on adjustments made using engineering judgement

Slide 43

Example of Performance Model



Slide 44

Superior Performing Pavements

- Use of PMS database to locate superior performing pavements
- Evaluate reasons for superior performance of these pavements
- Improve and upgrade performance and design models accordingly

11/15/2002 Module 4 44

Slide 45

PMS Data & Performance Models are valuable:

Since 1988 two elements helped convince legislature to increase funding:

1. high quality of PMS data base
2. reliable performance curves showing budget was inadequate to maintain desired performance level

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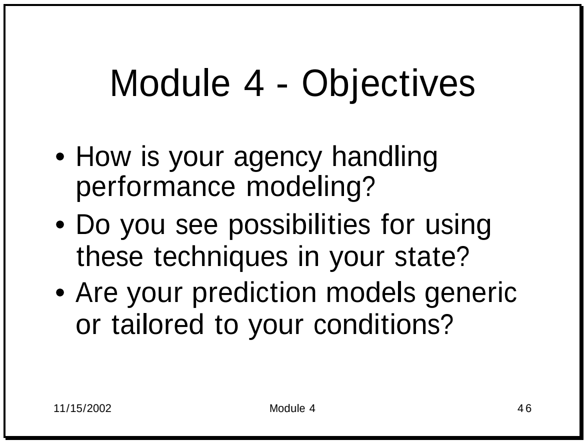
Slide 46


Module 4 - Objectives
• How is your agency handling performance modeling?
• Do you see possibilities for using these techniques in your state?
• Are your prediction models generic or tailored to your conditions?
11/15/2002
Module 4
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MODULE 5
5A – Day One
5B – Day Two

What Can Your Agency Do?

Module 5
What Can Your Agency Do?
Instructional Time: 15 minutes

Participant Questions

1. How can you monitor performance of Superpave using PMS and related data?

2. How should you use maintenance data in a PMS?

Slide 1

Module 5 - Workshops

What can your agency do?

11/15/2002 Module 5 1

Slide 2

Module 5 – Workshop Objectives

- Review Needs for Engineering Analysis in Agency of participants
- Discuss possibilities for implementation of Workshop recommendations and ideas

11/15/2002 Module 5 2

Slide 3

Workshop Procedures (1)

Divide participants into diverse subgroups – maximum 10 persons per subgroup

The group selects:

- A chair person or moderator
- A recorder to make notes
- A scribe to write key points on visual pad
- A reporter (usually separate from chairperson) prepared to report findings for discussion to main group which will reassemble after break out sessions.

11/15/2002 Module 5 3

Slide 4

Workshop Procedures (2)

Timing for Workshops will be flexible, with following approximate schedule:

- 60 min for discussions within Subgroups, incl. preparation of notes and key points on visual pad
- 30 min for class presentations by Subgroups
- 15 min for discussions amongst all participants

Slide 5

Module 5-a What Can Your Agency Do? (Workshop 1)

How to monitor performance of Superpave using PMS and related data:

- Database needs: PMS, QC/QA, mix design, pavement design
- How to obtain data from various disciplines
- How to link performance data to other data for each individual location
- Organizational consequences for DOT

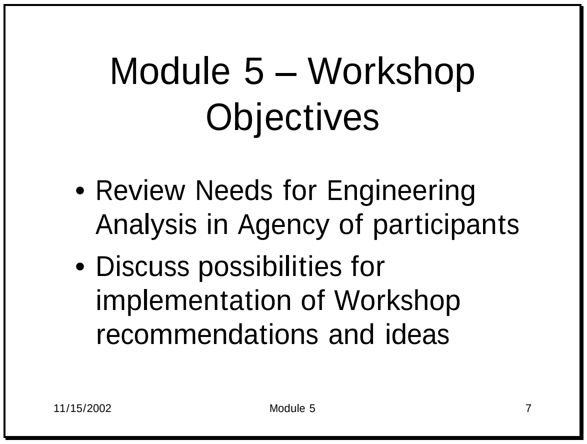
Slide 6

Module 5-b What Can Your Agency Do? (Workshop 2)

How to make use of maintenance data in a PMS:

- What maintenance data are relevant
- What are consequences for performance data collection
- Where need PMS to be modified
- How can MMS be linked to PMS
- Organizational consequences for DOT

Slide 7



Module 5 – Workshop Objectives
• Review Needs for Engineering Analysis in Agency of participants
• Discuss possibilities for implementation of Workshop recommendations and ideas
11/15/2002
Module 5
7

MODULE 6

Pavement (Overlay) Design Evaluation Analysis

Module 6
Pavement (Overlay) Design Evaluation Analysis
Instructional Time: 60 minutes

Participant Questions

3. What overlay design method do you use in your organization?

4. Has it ever been tested and compared with actual observed performance in practice?

Slide 1

Module 6
Pavement (Overlay) Design Evaluation analysis

Examples of Engineering Analysis in:

- Washington State DOT
- Texas State DOT
- Arizona State DOT

Slide 2

Module 6 - Objectives

- Demonstrate importance of engineering evaluation in design and overlay models
- Compare results among States
- Identify and illustrate various benefits

Slide 3

WSDOT - SCOPER Overlay Design Method

- A systematic way of estimating overlay thickness for a rehabilitation program
- 80% of designs do not have to be changed at project stage

Slide 4

SCOPER Background

- Originally WSPMS applied "standard fix" for pavement rehabilitation based on pre-selected minimum PCR
- Goal: estimate AC overlay thickness
- Use made of Asphalt Institute component analysis method, modified by WSDOT, in OVERDRIVE program

Slide 5

Overlay Scoping Technique

- Total pavement structure developed as new full depth AC design
- Uses pavement type & condition, thickness, subgrade modulus, and traffic
- Judgement required for weighting factors to evaluate existing structural integrity
- Overlay thickness = [required thickness for new design] - [equivalent thickness of existing AC pavement]

Slide 6

Illustration of SCOPER

- Design ESALs = 1,000,000 (assumed)
- Subgrade resilient modulus = 12,500 psi (known or calculated from deflections)
- Full-depth new AC=8.0" (calculated from AI-manual)
- Existing pavement structure
  - 4.2 inches AC (PSC = 60; thus "C" = 0.72)
  - 9.6 inches crushed stone base (coefficient 0.30)
- Convert existing pavement to full-depth AC
  - AC: 4.2" x 0.72 = 3.0"
  - Base: 9.6" x 0.30 = 2.9"
  - Total = 5.9"
- "Scoped" overlay thickness 8.0 - 5.9 = 2.1"

Slide 7

Review of Pavement Design Practices

- Regional engineers design pavements
- Each design reviewed by central office (Service Center)
- WSPMS makes review quick and effective using well maintained PMS data base

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Slide 8

Design Review Case Study

- Five miles of section of State Road 395
- 1994 condition survey
  - 5 to 15 % low to medium alligator cracking
  - 30 % medium to high longitudinal cracking
- 1994 PSC - 58, projected to 50 in 1995
- Subgrade Soil: Hodgson Silt Loam (ML)
- Base material: 230 - 460 mm silty sandy gravel
- Base Course: 80 mm crushed stone base
- Wearing Course: 100 - 300 mm AC.

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Slide 9

Case study using three overlay design methods

- 1. SCOPER based on Asphalt Institute Method (Mechanistic-Empirical)
- 2. EVERPAVE, developed by WSDOT (Mechanistic-Empirical)
- 3. DARWin, based on AASHTO's Guide for Design of Pavement Structures (Mechanistic-Empirical)

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Slide 10

EVERPAVE Method

- Evaluate effects of subgrade stiffness by back calculating 3 levels (low, medium, high stiffness)
- Account for stress sensitive unbound materials
- Define material properties of each layer, traffic load repetitions and environmental factors
- Compare service lives for fatigue and rutting with projected design ESAL
- Overlay thickness is that which ensures adequate service life for failure criteria (fatigue and rutting)

Slide 11

DARWin Method

- Determine structural number for future traffic SN_f from ESAL's, Initial and terminal serviceability and subgrade modulus (FWD, lab testing, empirical graphs)
- Determine existing structural number SN_{eff} from FWD testing (subgrade and pavement strength) and pavement thickness
- The required overlay structural number SN_{ol} is the difference between SN_f and SN_{eff}.
- Overlay thickness is SN_{ol} divided by a coefficient

Slide 12

Overlay Thickness Comparison

Core	EVERPAVE		AASHTO DARWin		WSPMS SCOPER	
Location	mm	*inch*	mm	*inch*	mm	*inch*
207.85	50	*2.0*	0	*0*	71	*2.8*
208.00	40	*1.6*	0	*0*	55	*2.2*
208.50	10	*.4*	0	*0*	56	*2.2*
209.00	95	*3.8*	127	*5.0*	147	*5.8*
209.05	100	*4.0*	132	*5.2*	155	*6.1*
209.40	110	*4.3*	135	*5.3*	143	*5.6*
209.80	35	*1.6*	0	*0*	65	*2.6*
210.00	60	*2.4*	58	*2.3*	118	*4.7*
210.50	35	*1.6*	0	*0*	90	*3.5*
211.00	10	*.4*	0	*0*	0	*0*
211.50	10	*.4*	0	*0*	0	*0*
212.00	10	*.4*	0	*0*	0	*0*
212.50	10	*.4*	0	*0*	0	*0*

Slide 13

Conclusions

- Design of overlays greatly facilitated by availability of well-maintained PMS data base
- Performance data used for all overlay design methods, but for mechanistic design elements extensive use made also of project and structural data
- In WSDOT at present time at 80% of time SCOPER gives right answer

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Slide 14

Texas State DOT's Engineering Analysis Elements

- Module 6:
  - Overview of TxDOT PMIS
  - Analysis of relation between subgrade properties and pavement rutting
- Module 7:
  - Performance of aggregates in concrete pavements
- Module 8:
  - District level index to select preventive maintenance projects

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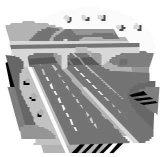
Slide 15

What is the Texas PMIS



An automated system for storing, retrieving, analyzing, and reporting information to help with pavement-related decision-making processes

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Slide 16

Primary Elements and Products of PMIS

- Inventory of pavements in the network
- Database of past and current pavement conditions
- Budget requirements
- Methods for optimizing and prioritizing projects

Slide 17

Pavement Types Surveyed

- Flexible pavement
  - Aggregate base with surface treatment
  - Aggregate base with hot mix A.C.
- Jointed concrete pavement
- Continuously reinforced concrete pavement

Slide 18

Flexible Pavement Distress

- Rutting
  - shallow & deep
- Patching
- Failures
- Cracking
  - block, alligator, longitudinal, transverse
- Optional:
  - Raveling
  - Flushing

Slide 19

JCP Distress

Distress score from:

- Failed joints and cracks
- Failures
- Slabs with longitudinal cracks
- Shattered slabs
- Concrete patches
- Apparent joint spacing

Slide 20

CRCP Distress

- Spalled cracks
- Punchouts
- Asphalt patches
- Concrete patches
- Average crack spacing

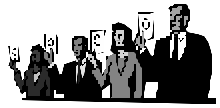
Slide 21

Distress Score Classes

DISTRESS SCORE	CLASS	DESCRIPTION
90-100	"A"	Very Good
80-89	"B"	Good
70-79	"C"	Fair
60-69	"D"	Poor
1-59	"F"	Very Poor

Slide 22

Scores



- Visual Distress (1 -100)
- Ride (0.1 - 5.0)
  - Profiler/rutbar vehicle
- Structural Strength (1 -100)
  - FWD measurements
- Condition (Composite 1 - 100)
  - combination of ride and distress

Slide 23

Analysis of Relationship between Rutting and Material Properties (Subgrade and Pavement Layers)

Slide 24

Texas PMIS Data Showed:

- Rutting increase between 1983 and 1987
- Greatest increase in 1987, particularly for Hot-Mix pavements
- Some districts were clearly more affected than others

Slide 25

Major Concerns About Rutting in Hot-Mix Pavements

- Effectiveness of expensive Hot-mix
- Typically used on higher traffic highways, difficult repair scheduling
- Safety risks of deep ruts
- Premature failures present poor image

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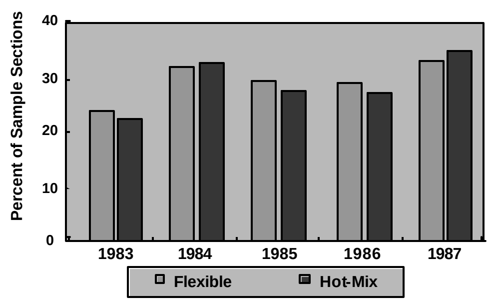
Rutting as % of Sample Sections Flexible Vs. Hot-Mix PMIS Sections



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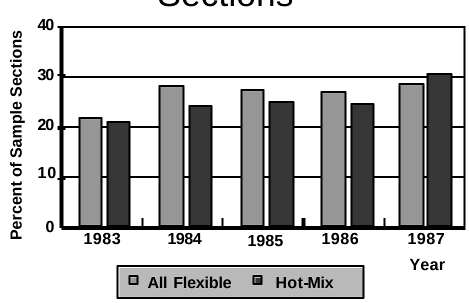
1/2”- 1” Rutting as % of Sample Sections



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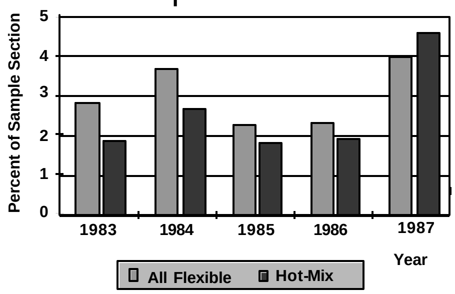
More than 1” Rutting as % of Sample Sections



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Slide 29

Testing of structural pavement and subgrade properties

- Used FWD data collected for PMIS
- Expressed calculated subgrade strength in resilient subgrade modulus
- Stiffness of base and surface layers related to surface curvature index (SCI)
- Results averaged per county and plotted on maps.
- Measured rutting plotted in similar fashion

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Slide 30

Subgrade Properties

Category	Subgrade Modulus (psi)
Very Poor	0 - 12,999
Poor	13,000 -17,999
Fair	18,000 - 22,999
Good	23,000 – 27,999
Very Good	28,000 - 199,999
State average	*20,652 for all pavements*
(Fair)	*20,495 for Hot-mix areas*

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Pavement Stiffness

Category	SCI value
Very Poor	25.00 – 99.99
Poor	19.00 – 24.99
Fair	13.00 – 18.99
Good	7.00 – 12.99
Very Good	0 – 6.99
State average	*16.58 for all pavements*
	12.24 for Hot-mix

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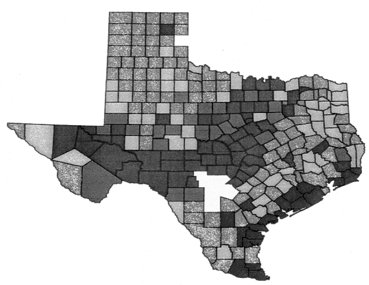
SUBGRADE SUPPORT

1987 PES — MAINLANE FWD SECTIONS

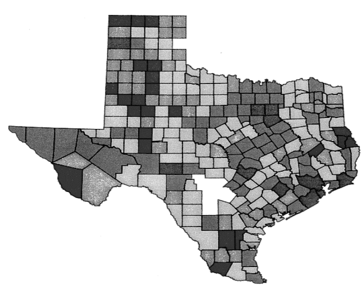


11/15/20(MEANSS VERY POOR GOOD POOR VERY GOOD FAIR 32

Slide 33

BASE/SURFACE STIFFNESS

1987 PES — MAINLANE FWD SECTIONS



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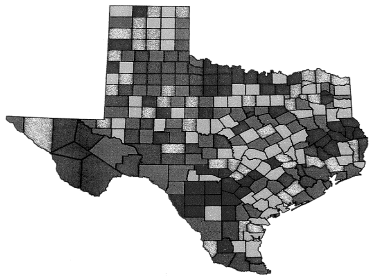
RUTTING ON TEXAS HIGHWAYS

1987 PES -- MAINLANE ACP SECTIONS



PCTRUT87
0-12.5%
25.01-37.5%
OVER 50.0%
12.51-25.0%
37.51-50.0%

Slide 35

Rutting depends on:

Subgrade strength, but also on:

- Asphalt mix design
- In-place asphalt mix properties
- Amount of traffic loads
- Temperature and traffic speed
- Thickness design

Slide 36

Conclusions

- Subgrade strength is only one parameter affecting rutting tendency
- No clear pattern between rutting and subgrade properties emerged
- Effects of district boundaries could have been caused by other parameters, such as mix design and quality control
- Demonstrated need for review of mix design and construction techniques

Slide 37

Results of Study

- Changes were made in the hot-mix specifications, and performance based specifications were initiated
- Improved rutting resistance of these new mixes is being tested in practice
- The PMIS database supplied much-needed help for the study.

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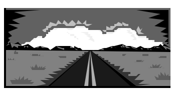
Overlay Design in Arizona with link to PMS database



Use of SODA as in-house development and implications of possible switch to DARWin.

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Original SODA Development

- SODA (Structural Overlay Design for Arizona) was developed in early eighties
- Deflections measured with Dynaflect
- Deflection data linked to PMS database for traffic and environmental info, and for roughness of pavement prior to overlay.
- Overlay thickness calculated by SODA in DOS environment

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Original SODA Development
(continued)

- Overlay thickness function of:
  - ESAL's,
  - Regional Factor,
  - SIB (shape of deflection bowl),
  - D5 (Dynaflect deflection furthest from load),
  - Roughness prior to overlay.
- Overlay thickness not dependent on:
  - Deflection under center of load
  - Existing pavement thickness

Slide 41

SODA Modifications

- Dynatest FWD with conversion factors
- Overlay thickness cut off at 6" at high range and 2.5" at low range.
- Small D5 results in over design, large D5 results in under design, in both cases compensation required.
- Thickness equation modified to reflect experience.

Slide 42

DARWin Overlay Design

- DARWin (Design, Analysis,& Rehabilitation for Windows) based on AASHTO Design.
- DARWin can be linked to PMS database
- Overlay design module of DARWin can design 7 types of overlays using 3 different methods.
- Method based on difference between future SN_f and existing SN_{eff}

Slide 43

DARWin Overlay Design
(continued)

- $SN_{ol} = a_{ol} * D_{ol} = SN_f - SN_{eff}$
  - a_{ol} is structural coeff. for asphalt overlay
  - D_{ol} is required overlay thickness
- SN_f determined from design ESAL's, subgrade modulus (FWD, lab, graphs), initial & terminal serviceability
- SN_{eff} determined from Component Analysis, Remaining Life, or FWD testing:
  - Calculate modulus of all layers & subgrade
  - Assess thickness of pavement layers above subgrade

Slide 44

Comparison SODA/ DARWin

- Both methods sensitive to ESAL's & regions.
- SODA sensitive to roughness prior to overlay, DARWin is not.
- DARWin sensitive to pavement thickness, initial and terminal serviceability and several other parameters while SODA is not
- DARWin uses all deflection points, SODA only uses shape of deflection bowl and D5
- A smaller D5 increases overlay thickness in SODA, but decreases thickness in DARWin

Slide 45

DARWin Analyses for historic SODA projects

- 21 DARWin runs, projects from '86 to '98
- In 5 cases DARWin produced similar thickness as SODA (within 1 inch),
- In 7 cases DARWin produced smaller thickness,
- In 9 cases DARWin produced larger thickness

Slide 46

DARWin Analyses for historic SODA projects (continued)

- Designers adjusted SODA outcome frequently, as it appears mostly in line with DARWin output
- Average overlay thickness found:
  - calculated with SODA 3.5”
  - calculated with DARWin 3.9”
  - actually selected overlays 4.5”

Slide 47

Conclusions (1)

- DARWin seems good alternative to SODA:
  - Modern computer technology, easy link to PMS databases
  - User friendly, flexible, AASHTO compatible
- On average the overlay thickness for historic projects found with DARWin are between SODA output and actual thickness chosen by pavement designers

Slide 48

Conclusions (2)

ADOT’s change to new technology was facilitated by the availability of a good PMS Database

Slide 49

Module 6 - Objectives

- What overlay design method is used in your agency?
- Are PMS data used in your agency for overlay design?
- Has the overlay design method ever been tested and compared with observed performance?

MODULE 7

Pavement Materials & Construction Performance

Module 7
Pavement Materials &
Construction Performance
Instructional Time: 70 minutes

Participant Questions

1. Name any materials or construction techniques used in your agency that we have not discussed?
2. Any new materials?
3. What are they?
4. What are the latest trends in construction in your state?

Slide 1

Module 7:
Materials & Construction Performance Evaluation

- Materials and Construction Performance Overview
- Examples of engineering analysis in:
  - Arizona State DOT
  - Texas State DOT
  - Kansas State DOT

Slide 2

Objectives of Module 7

- Define importance of engineering analysis for materials and construction
- Illustrate and contrast engineering analysis with three practical state examples

Slide 3

Pavement Materials

- Asphalt surface treatments
- Portland cement concrete, with or without reinforcing steel
- Asphalt concrete & other mixes
- Granular base and subbase
- Asphalt, lime, & cement treated base
- Subgrade materials
- Additives (rubber, adhesion agents)

Slide 4

Fundamental Material Characterization

- **Empirical** material characterization
- **Mechanistic** evaluation requires mechanistic testing procedures

Slide 5

Asphalt Hotmix Properties

- Mixture Stiffness
- Resistance to permanent deformation
- Durability
- Fatigue resistance
- Low temperature response
- Permeability

Slide 6

Stabilized Materials

- Cement-stabilized bases are nonlinear elastic
- Asphalt-stabilized bases are nonlinear visco-elastic

Slide 7

Soils and Granular Materials

- Either cohesive or cohesionless
- Properties influenced by:
  - Moisture content
  - Aggregate shape and angularity
  - Grading
  - Stress level

Slide 8

Cohesive Soils

- Stress history may have a significant effect on response
- Clay and other cohesive soils are highly nonlinear
- Moisture may have effect on volumetric expansion

Slide 9

Summary for Materials

- As-constructed material properties are important to the performance of pavements
- Material properties should be recorded with the best information available
- Most PMS will limit the detail that can be recorded

Slide 10

Construction Overview

- The interrelationships of construction with other phases of PMS
- Construction data documentation for use in PMS Database

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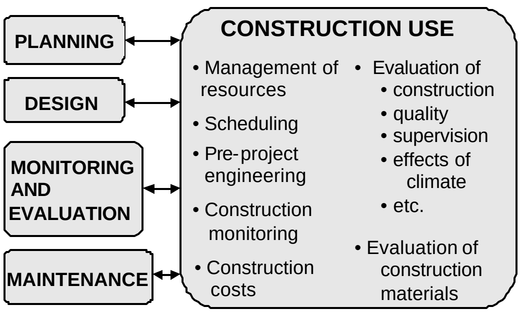
Slide 11

Information to/from Construction



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Construction Documents

- Drawings or project plans with location, dimensions, etc
- Specifications for specific projects
- General “standards and specifications”

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Slide 13

Types of Specifications

- Traditional specifications
- Specifications with penalty and bonus clauses
- End product specifications
- Performance based specifications

Slide 14

Construction Provides Documentation for PMS

- Pavement structure: type, thickness, location
- Materials: properties, variations, quantities
- Costs: total and unit costs
- Construction dates and times
- Environment: weather, drainage problems, etc
- Traffic during construction, traffic measures
- Initial Structural Capacity of pavement
- Initial Roughness of pavement

Slide 15

PMS Modeling to Compare Treatments and Materials for Arizona DOT

5 Functional Treatments
11 Structural Treatments

Slide 16

Functional Treatments

SC	Seal Coat
FC	Open Graded Asphalt Concrete Friction Course
FR	Open Graded Asphalt Concrete Friction Course with Asphalt Rubber
RE-FC	Mill + Fill with Asphalt Concrete Friction Course
RE-FR	Mill + Fill with Asphalt Concrete Friction Course with Asphalt Rubber

Slide 17

Structural Treatments

AC	Asphalt Concrete Overlay
AC-SC	AC + Seal Coat
AC-FC	AC + Asph.Concr.Frict.Course (FC)
RC	Recycle in place
RC-AC-FC	Recycle in place + AC+ FC
RE-AC	Mill + AC
RE-AC-FC	Mill + AC + FC
RE-AC-FR	Mill + AC + Asph.Rubber FC
RE-AR	Mill + AC with rubber
RE-RC-FC	Remove + Recycle/replace + FC
RE-RC-AC-FC	Remove + Recycle/repl. + AC + FC

Slide 18

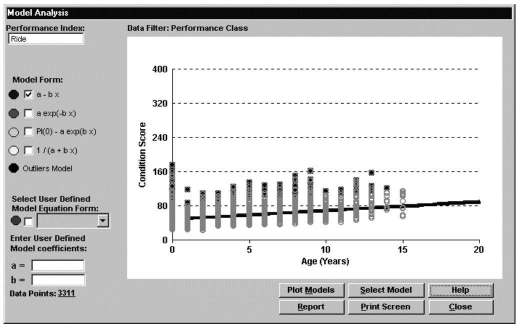
Organizing the Data

1. Data set developed for 16 treatments for period ‘81-’95. Number of records per treatment varied between 11 and 17187.
2. Data set imported into Visual Modeler for analysis.
3. Performance indicators (PI) Roughness, Friction, Cracking and Rutting were evaluated.
4. Treatments divided over several groups, dependent on relevance for PI

Slide 19

Example of Data Analysis (1)
Many data points, generally good fit

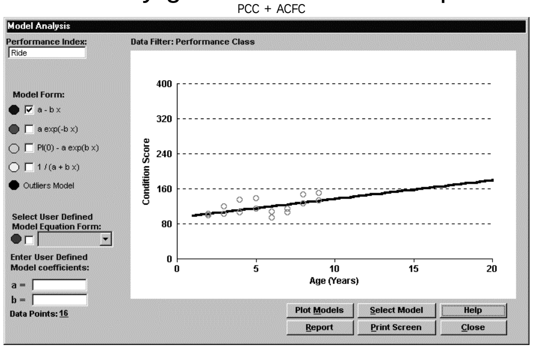
RCACFC



Slide 20

Example of Data Analysis (2)
Generally good fit for few data points

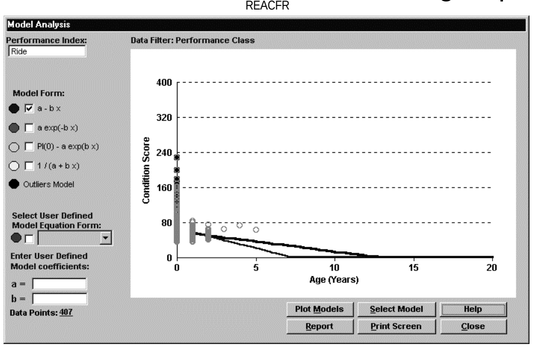
PCC + ACFC



Slide 21

Example of Data Analysis (3)
Poor fit, biased distribution, wrong slope

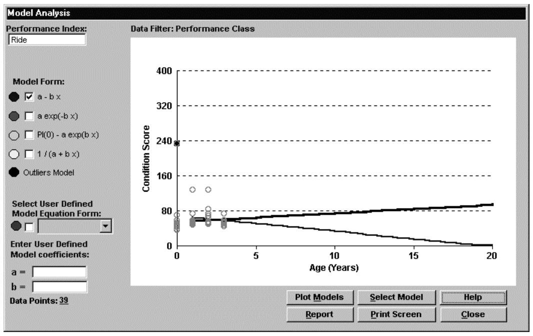
REACFR



Slide 22

Example of Data Analysis (4)
Short timeframe, good fit without outlier

REAR



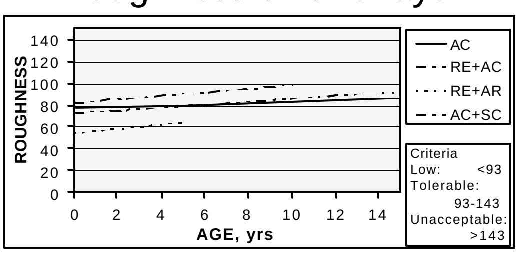
Slide 23

Grouping used for Roughness Evaluation

- Structural Overlays, incl. Surf. Treatments
  - AC-REAC-REAR-ACSC
- Structural Overlays + Friction Courses
  - ACFC-REACFC-REACFR
- Functional Overlays
  - FC-SC- FR- REFC-REFR
- Recycling Treatments
  - RC-RCACFC-RERCFC-RERCACFC

Slide 24

Roughness of Overlays



Code	Description	Nr. of Records	Max Age	Significance
AC	Asphalt Concrete	1254	15	High
REAC	Layer removal + AC	539	10	High
REAR	Layer removal + Rubber AC	39	5	Very Low
ACSC	AC + Seal Coat	7205	15	High

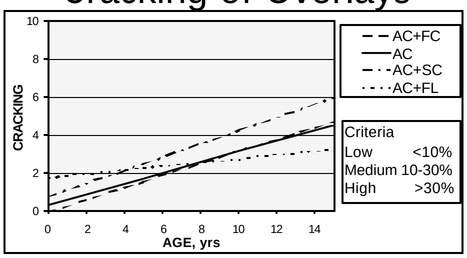
Slide 25

Grouping used for Cracking Evaluation

- Structural Overlays with Surface Treatments
  - AC-ACSC-ACFC-ACFL
- Layer Removal & Structural Overlays
  - REAC-REAR-REACFC-REACFR-REACSC
- Recycling Treatments
  - RC-RCACFC-RERCFC-RERCACFC-ROFC
- Functional Treatments
  - SC- FC-REFC-FR-REFR

Slide 26

Cracking of Overlays



Code	Description	Nr of Records	Max Age	Significant
AC	Asphalt Concrete	1237	15	Yes
ACFC	Asph. Concr.+ FC	8364	15	Yes
ACSC	Asph. Concr.+ Seal Ccat	7210	15	Yes
ACFL	AC + Flush Coat	756	15	Yes

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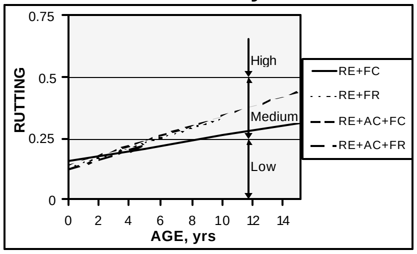
Grouping used for Rutting Evaluation

- Structural Overlays including Friction Courses and Rubber
  - AC-ACFC-REAC-REAR
- Layer removal + Friction Courses with/ without Structural Overlays & Rubber
  - REFC-REFR-REACFC-REACFR
- Recycling Treatments
  - RC-RCACFC-RERCFC-RERCACFC

Slide 28

Rutting of Friction Courses after layer removal, incl. Overlays and Rubber



Code	Description	Nr of Records	Max Age	Significant
REFC	Layer removal + FC	558	15	Yes
REFR	Layer removal + Rubber FC	171	10	Yes
REACFC	Layer rem.+AC+ Frict.Course	2742	15	Yes
REACFR	L.removal +AC+ RubberFC	407	5	No

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Good Performers

Roughness	Friction	Cracking	Rutting
AC	SC	AC	AC
AC-FC	FR	AC-FL	RE-AC
FC	RE-AC	FR	RE-FC
RE-FC	RE-FR	RE-AR	RE-AC-FR
RE-FR		RE-FC	RE-RC-AC-FC
RC-AC-FC		RE-FR	
RE-RC-AC-FC		RE-AC-SC	
		RE-RC-AC-FC	

Slide 30

Limitations

- Complete comparison includes cost, construction time and delays, environmental aspects, etc
- <u>Condition</u> prior to overlay (not recorded) can have major influence on performance
- <u>Existing structure</u> (not recorded, except wearing course) has influence on roughness, cracking and rutting.

Slide 31

Conclusions

- Performance modeling is suitable tool to evaluate various rehabilitation treatments for range of performance indicators and various circumstances,
- The success of any engineering analysis depends largely on suitability, completeness and accessibility of PMS databases.

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Use of PMIS Database to Solve PCC Pavements Engineering Problems in Texas

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University of Texas Study

- Center for Transportation Research (CTR) of UT maintained Rigid Pavement survey database since 1974
- In early 80's surveys indicated many CRCP pavements showed early signs of distress
- Since no obvious reasons for failure were evident, as first step database was studied

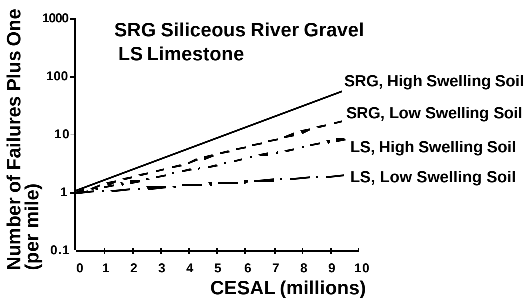
Slide 34

Use of CTR/PMIS Database

- PMIS database indicated a diversity of performance among CRCP pavements.
- County in which pavement was located correlated well with observed damage.
- Generally particular aggregate type is common within a particular county
- Cause found was type of aggregate used: CRCP with limestone (LS) performed much better than with siliceous river gravel (SRG)

Slide 35

Example of Distress Curves



Slide 36

Observations from study

Good correlation between computer model, laboratory- and field tests

Significant differences between paired test sections:

- Limestone
  - Fewer cracks
  - Larger crack spacing
  - Smaller crack widths
- Siliceous river gravel
  - Early minor punchouts
  - Seasonal influence on crack width

Slide 37

Summary of Aggregate – Steel – Crack Relationships

Limestone	Siliceous River Gravel
Fewer Cracks	More Cracks
Larger Crack Spacing	Smaller Crack Spacing
Smaller Crack Width	Larger Crack Width
Design Calls for Higher % Steel	Design Calls for Lower % Steel

Slide 38

Findings of Engineering Application

- Additional data and engineering analysis are needed
- PMIS can help in providing data for engineering study

Slide 39

Joint Effort Investigations

- Heat of hydration effects on early-age behavior of CRCP
- Effect of construction season (temperature) on early-age cracking
- Detrimental characteristics of early cracks
- Effect of coarse aggregates on cracking
- Factors affecting crack width
- Determination of setting temperature
- Correlation between field and laboratory cracking
- Simulation of distress in computer program

Slide 40

Kansas State DOT's Engineering Analysis Elements

- Overview of KDOT's PMIS
- Smoothness specifications to maintain construction quality control (with bonus or penalty)

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Overview of KDOT PMIS

- Network Optimization System (NOS) using 3 distress variables to derive optimum list based on linear programming
- Project Optimization System (POS), prediction models currently being revised

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PMIS Database

• Portland Cement Concrete	700 miles
• Composite	1,100 miles
• Full Design Bituminous	2,800 miles
• Partial Design Bituminous	5,400 miles
• TOTAL	10,000 miles

Reference system is county/route/milepost

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KDOT'S Two Programs

- Large projects, often selected on "worst first" basis, including formula for traffic, age , funding, etc
  - 100 - 200 miles per year reviewed by peer group as part of project selection
- Rehabilitation of 1,200 miles per year using state funding (NOS)
  - 1,000 miles FWD testing per year

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NOS Requires Roughness, Rutting & Transverse Cracking Information

Examples of Severity Levels

Levels	Roughness	Rut Depth
1	<1.66 m/km	<13 mm (1/2")
2	1.66 to 2.59 m/km	13 to 25 mm (1/2 to 1")
3	>2.59 m/km	>25 mm (1")

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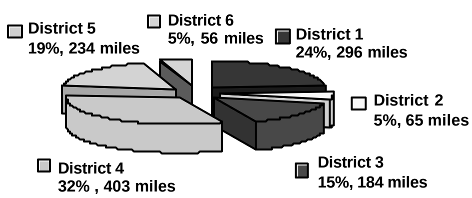
Distribution of Rutting by District

1989



Length of Level 2 and 3 Rutting (>13 mm) with total of 1238 miles
Length of total Network 10,000 miles

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Project Level Optimization System (POS)

- Projects selected by districts - reviewed by design team at state level considering distress etc, but no formal decision program
- POS currently being revised

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Slide 47

Developing Performance Models

- Data is collected on three randomly selected 30 m (100') subsections per mile
- Results in almost no repetitive data, lack of year-to-year continuity and consequently difficulty in upgrading performance models
- Points out need for research element in PMS

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As-Constructed Smoothness Specifications

- Kansas changed their roughness specification to include initial smoothness control
- PMIS has verified pavements
  - are now smoother
  - now have longer lives

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Surface Smoothness on Newly Constructed Pavements

- Major Concern of highway industry
- Primary purpose of smoothness measurement is construction quality control
- Directly affects public - road users
- Pavement profiles with short wavelength and amplitudes <5mm (0.2”) can harm ride quality and should be avoided

Slide 50

Development of AC Smoothness Specifications

- KDOT eliminated blanking band width in profilograph trace reduction process
- Incentive payments to contractors compatible with those for concrete pavements first introduced in 1985
- Increase in number of sections in bonus range indicates success of approach, resulting in smoother AC pavements

Slide 51

Major Elements of new AC Smoothness Specifications

- Mainline pavements > 100 mm (4”) thick
- Single set of specifications regardless of speed limit, route type, & functional class
- Excludes bridges, shoulders, short sections and others
- Similar to PCC incentives
- Smoothness is separate pay item
- Threshold target requiring remedial action

Slide 52

Schedule for Adjusted Payment for AC, Similar to PCC,

with 5mm (0.2”) Blanking Band

Profile Index (PRI) (mm / km per 0.16 lane km)	Contract Price Agreement per 0.16 lane km (Dollars)
32 or less	**+152.00**
32.1 to 47	**+76.00**
47.1 to 142	**0.00**
142.1 to 174	**-102.00**
174.1 to 205	**-203.00**
205.1 to 237	**-254.00**
237.1 or greater	**-305.00**

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Effects of 1990 Profilograph Results for 2 Blanking Bands

PRI = Profile Index

No. of .16 km sections	**Compliance with specified PRI (mm/km) for 0.2” and 0.01” Blanking**					
5mm (0.2”) blanking	PRI 0-47 Bonus	(%)	PRI 47-142 Full Pay	(%)	PRI >142 Penalty	(%)
851	547	64	226	27	78	9
.25 mm (0.01”) blanking	PRI 0-158 Bonus	(%)	PRI 158-631 Full Pay	(%)	PRI >631 Penalty	(%)
842	71	8	753	90	18	2

Slide 54

Adjusted Payments for AC Pavements (1991)

Profile Index (PRI) **(mm per km / 0.16 lane km)**	Contract Price Agreement **per 0.16 lane km (Dollars)**
110 or less	**+152.00**
110.1 to 158	**+76.00**
158.1 to 473	**0.00**
473.1 to 631	**0.00 (correct back to 394 mm/km or less)**
631.1 to more	**-203.00 (correct back to 394 mm/km or less)**

Slide 55

Profilograph results with 1993 Zero .25 mm (0.01”) Blanking Band

Roadway	No of 0.16 kilometer sections	Compliance with specified PRI (mm/km)					
		PRI (0-158) Bonus	(%)	PRI (158.1-631) Full-pay	(%)	PRI (>631) Penalty	(%)
1990 (reanalysis)	842	71	8	753	90	18	2
1991 (reanalysis)	1890	57	3	1796	95	37	2
1992	5866	1467	25	4341	74	58	1
1993	4568	625	15	3499	84	42	1

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Results of Cost Analysis of AC Pavement Smoothness Specifications

Year	No. Of 0.16 km Sections	Bonus ($)	Bonus/ Lane km Paved ($/km)	Penalty ($)	Penalty Lane km Paved ($/km)
1991	**1890**	**4256**	**14.07**	**7919**	**26.19**
1992	**5866**	**191084**	**203.59**	**4060**	**13.43**
1993	**4568**	**94488**	**129.25**	**3857**	**12.75**

Slide 57

Conclusions

- Availability of distress and other data in PMIS database essential for study
- Smoothness specifications evolved over several years
- Implementation of zero blanking band resulted in better pavements
- Incentive payments encouraged better paving

Slide 58

Objectives of Module 7

- Why is engineering analysis important for materials and construction?
- Has your agency experience with engineering analysis for materials and construction?

MODULE 8

PMS for Tracking Preventive Maintenance Actions

Module 8

PMS for Tracking Preventive Maintenance Actions

Instructional Time: 40 minutes

Participant Questions

1. Is your agency using PMS to track the performance of preventive maintenance?
2. How are you doing that?
3. Does your organization have a separate budget for preventive maintenance?
4. Does your agency make a clear distinction between preventive maintenance and preservation?

Slide 1

Module 8
Preventive Maintenance

Case Studies About the Role of PMS in Tracking the Performance of Preventive Maintenance Actions

Slide 2

Module 8 - Objectives

To examine and define the role that PMS data can play in:

- Development and implementation of Preventive Maintenance programs, and
- Tracking the performance of Preventive Maintenance projects.

Slide 3

Possible Actions

- Preventive Maintenance
- Preservation (Corrective Maintenance)
- Rehabilitation
- Reconstruction

Many Different Definitions

Action is often based more on Fund availability than any specific definition

Slide 4

AASHTO's Definition of Preventive Maintenance

The planned strategy to apply cost effective treatments to an existing roadway system and its appurtenances to preserve the system, retard future deterioration, and maintain or improve the functional condition of the system.

-*AASHTO's Standing Committee on Highways*

Slide 5

Preventive versus Corrective Maintenance

- Preventive Maintenance actions should be taken before noticeable deterioration to increase life
- Preservation (Corrective) Maintenance is taken after deterioration to correct damage and thus increase life

Slide 6

Examples of Preventive Maintenance Treatments (AASHTO)

- **AC Pavements**
  - Thin overlay
  - Mill and overlay
  - Chip seal
  - Microsurfacing
  - Crack treatment
  - Shoulder seals
  - Ultrathin Overlay
- **PCC Pavements**
  - Joint resealing
  - Spall repair
  - Crack sealing
  - Diamond grinding
  - Shoulder seals
  - Drain cleanout
  - Dowel retrofit
  - CPR

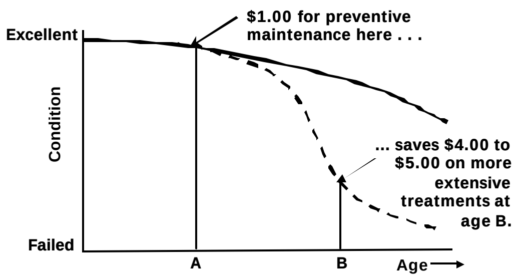
Slide 7

Importance of Timing

- Most important is to accomplish maintenance in a timely fashion, regardless of what it is called or where the money comes from
- However, if the proper maintenance can be done “before” deterioration, it usually saves money

Slide 8

Concept of Preventive Maintenance



Lower LCC of Preservation + Better Performance

Slide 9

Study sponsored by FHWA
Conducted by Dr. Gilbert Baladi

Case Studies in 2001, Baladi visited:

- Arizona DOT
- California DOT
- Georgia DOT
- Michigan DOT
- Montana DOT
- Pennsylvania DOT

Slide 10

Additional Studies

Case Studies in:

- Texas DOT:
  - District Level Index to Select TxDOT Projects for Preventive Maintenance
- Wisconsin DOT:
  - Preventive Maintenance Strategies for Continuously Reinforced Concrete Pavements

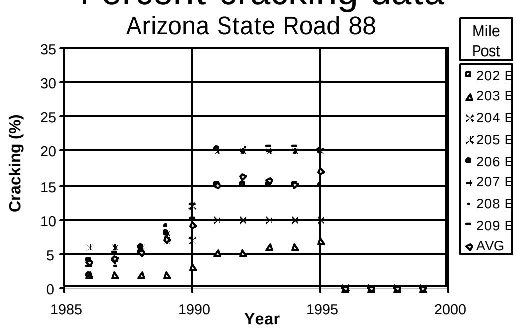
Slide 11

Scope of Baladi Study
6 States

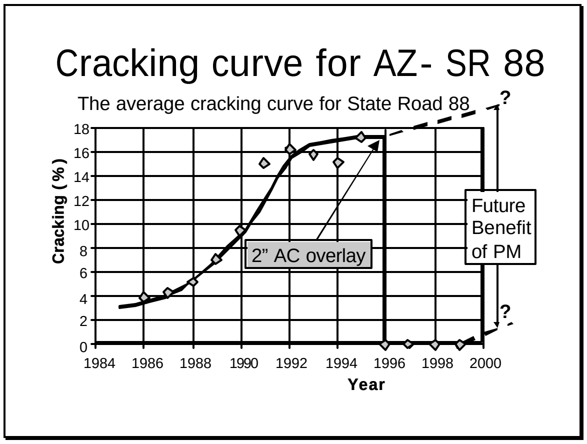
- To evaluate the state-of-the-practice of DOTs who developed and implemented a Preventive Maintenance (PM) program based on pavement needs.
- To investigate and analyze distress data used to select PM project boundaries, time for construction, and PM actions by the DOTs.

Slide 12

Percent cracking data
Arizona State Road 88



Slide 13



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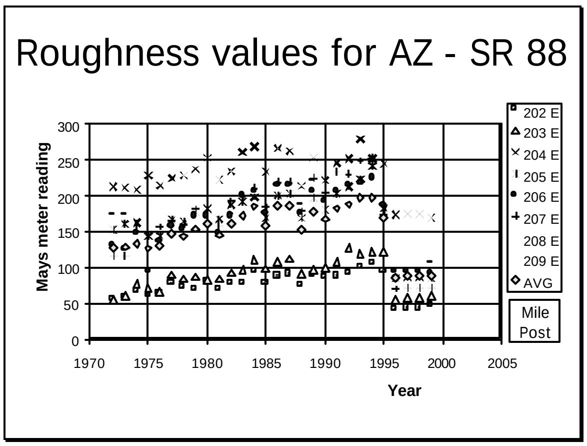

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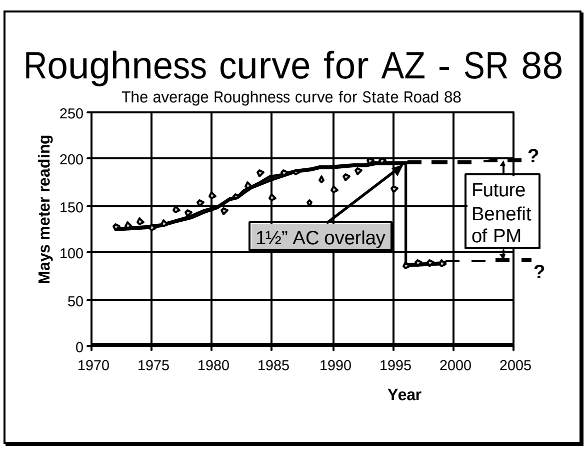


Slide 16

Preventive maintenance actions on State Road 16 in California

Section number	Preventive maintenance action	Age (years)	Pavement condition
1	½-in rubberized AC overlay	7	Very good
2	¾-in rubberized AC overlay	7	Very good
3	1-in rubberized AC overlay	7	Excellent
8	½-in rubberized AC overlay	7	Very good
9	¾-in rubberized AC overlay	7	Very good
12	1-in rubberized AC overlay	7	Excellent
Control	4-in AC surface	7	Patching in wheel paths due to alligator cracking
East of 15	1-in conventional AC overlay	2	Longitudinal and transverse cracks

Slide 17

Georgia DOT PM Actions for Rigid Pavements

- Slab replacement
- Under sealing
- Full-depth repair
- Partial-depth repair
- Joint resealing
- Diamond grinding to correct faulting and ride quality

Slide 18

Georgia DOT PM Actions for Flexible Pavements

- Microsurfacing
- 1.5-inch overlay
- Milling, Interstates: 3” mill and 4.5” fill
  State roads: Fill can be less than mill
- Crack sealing
- Slurry seal
- Surface treatment
- Patching
- Chip seal
- Chip seal interlayer and HMS overlay
- Shoulder paving

Slide 19

Georgia DOT Preventive Maintenance Strategies

1. Optimum timing of Actions
2. Adequate Preventive Maintenance Budget
3. Fast Track Response
4. Strict Specifications

Slide 20

Expenditures of Preventive Maintenance Program in Michigan

Year	Annual Budget (Million $)
1992	6
1994	16
1996	24
1998	54
2000	60

Slide 21

Michigan DOT PM Actions for Flexible & Composite Pavements

- Non-structural bituminous overlay
- Surface milling & non-structural
- bituminous overlay
- Chip seals
- Micro-surfacing
- Crack treatment
- Over-band crack filling
- Bituminous shoulder seal
- Ultra thin overlays

Slide 22

Michigan DOT PM Actions for Rigid Pavements

- Full depth concrete pavement repair
- Concrete joint resealing
- Concrete spall repair
- Concrete crack sealing
- Diamond grinding
- Dowel bar retrofit
- Concrete pavement restoration
- Bituminous shoulder seal
- Open-graded underdrain cleaning/repair

Slide 23

MDOT selection of PM treatment based on condition/benefits (1)

Flexible and Composite Pavements

TREATMENT	RSL years	Distress Index	RQI	Rut Depth (mm)	Life Extension years
Non-struct.bitum.overlay	3	<40	<70	<12	5 to 10
Surf.mill+non-st.bit.overl	3	<40	<80	<25	5 to 10
Double chip seal	5	<30	<54	<3	4 to 7
Single chip seal	6	<25	<54	<3	4 to 7
Micro-surfacing/multiple	5	<30	<54	<25	4 to 6
Micro-surfacing/ single	10	<15	<54	<25	3 to 5
Crack treatment	10	<15	<54	<3	Up to 3
Crack filling	7	<20	<54	<3	Up to 2
Ultra-thin bitumin.overlay	7	<20	<54	<3	no data

Slide 24

MDOT selection of PM treatment based on condition/benefits (2)

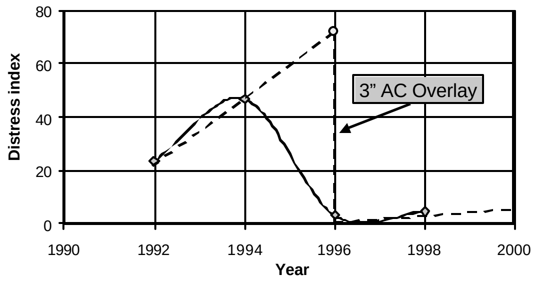
Rigid Pavements

TREATMENT	RSL years	Distress Index	RQI	Life Extension years
Full depth concrete pavement repair	7	<20	<54	3 to 10
Concrete joint resealing	10	<15	<54	3 to 5
Concrete spall repair	10	<15	<54	Up to 5
Concrete crack sealing	10	<15	<54	Up to 3
Diamond grinding	12	<10	<54	3 to 5
Dowel bar retrofit	10	<15	<54	2 to 3
Concrete pavement restoration	3	<40	<80	7 to 15

Slide 25

Average Distress Index curve

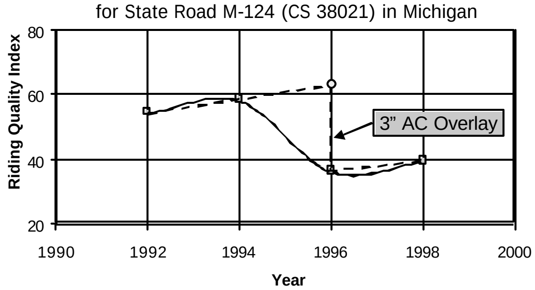
for State Road M-124 (CS 38021) in Michigan



Slide 26

Average Riding Quality Index curve

for State Road M-124 (CS 38021) in Michigan



Slide 27

Penn DOT Preventive Maintenance Actions for Interstate 78

- Mill the existing asphalt concrete
- Test all joints load transfer using FWD
- Repair deteriorated joints using full depth concrete patches
- Place asphalt concrete overlay
- Saw cut asphalt concrete to match PCC joints
- Seal saw cuts in the asphalt

Example of Difficulty in Defining Preventive Maintenance

Slide 28

Findings of Baladi Study

- This study shows potential value of Preventive Maintenance
- The study does not show follow-up data, however, the PMS provides a data base for storing relevant data
- The follow-up data could show actual benefits of Preventive Maintenance

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Slide 29

Results of Baladi Study

- The Baladi study shows "before and after" data. (Not really yet the proof we need).
- Continued observations and recording in the PMS data base can show the quantitative value of Preventive Maintenance. (Most DOT's don't have the data yet).

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District Level Index to Select TxDOT Projects for Preventive Maintenance

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Slide 31

Fort Worth District

- 8100 Lane Miles , divided over 8 counties
- Annual $7,000,000 Program
- Uses PMIS in combination with local area engineer's recommendations to select projects
- Needed new tool to select most critical projects for funding: District Level Index

Slide 32

District Level Index

- Index based on size, costs, age and needs of particular project
- Projects with highest priority are considered for funding
- Pavements younger than 5 years get low priority by setting age at 1.0 in index equation

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District Level Index Equation

Index involves:

Length: two lane roadway in miles
Cost: Dollars
Lane factor (LF): 1 for two lanes, 2 for multi-lanes
Age: time since last treatment (age< 5: value 1)
Needs: % of section requiring maintenance

Slide 34

Index Linked to PMS Data

- Length, LF, age and % needs provided by PMS database
- Cost estimates and priority recommendations provided by area engineers
- When area engineer high priority projects conflict with PMIS - pavement is re-inspected and decision made by him/her

Slide 35

Priority List for Index (Partial)

Description	Length miles	Age yrs	% Needs	Index	Cost '000$	Cum. '000 $
Seal Coat	4.3	9	4	1.0	52.1	52.1
Seal Coat	6.6	12	4	1.0	148.1	200.2
Seal Coat	4.1	15	1	1.0	47.0	247.2
Seal Coat	6.5	11	50	0.069	103.3	350.5
SC+Fog Seal	12.4	11	36	0.028	174.2	524.7
Slurry Seal	5.8	7	91	0.024	309.5	834.2
SC+ Latex	4.0	8	30	0.013	72.8	907.0

Slide 36

Summary of 1997 Program

- 126 projects submitted by area engineers, and prioritized according to index
- Only first 32 projects could be financed with $7,000,000 budget
- For first three projects with index=1 and very low value for %Needs the district overrode the prioritization.

Slide 37

Conclusions

- District level index is useful tool for establishing priorities in project selection
- The index makes use of PMIS data
- Ultimate responsibility for selection rests with the district PMS engineer.

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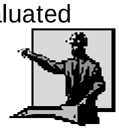
Slide 38

Preventive Maintenance Strategies for Continuously Reinforced Concrete Pavements

- Research Study carried out by WisDOT
- Several rehabilitation and preventive maintenance techniques evaluated since 1988



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Slide 39

Use of CRCP by WisDOT

- CRCP only used on high volume roads, 3.5% of total statewide mileage, or 475 miles
- WisDOT has two generations of CRCP:
  - Built with "black" steel in 60's and 70's
  - Built with epoxy coated "green" steel between '84 and '87.

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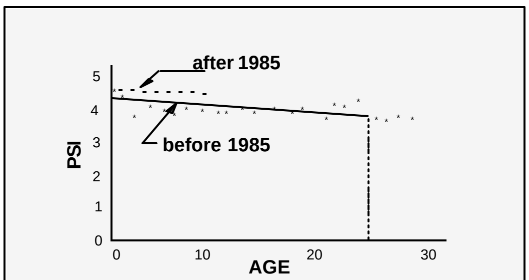
Slide 40

Performance of CRCP

- Outstanding performance on ride: average PSI > 4
- Structural performance worse than average for all pavements: PDI averages 44 (fair), for all pavements it is 37 (good).
- Poor structural performance main reason for study

Slide 41

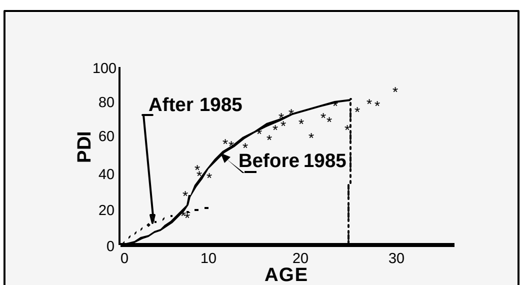
PSI vs Age for CRCP



RIDE vs AGE for TYPE 6 Pavements

Slide 42

PDI vs Age for CRCP



DISTRESS vs AGE for TYPE 6 Pavements

Slide 43

Structural Deterioration of CRCP

- "Black" steel pavements:
  - By age three cracks have formed
  - Steel reinforcement begins to corrode, causing structural problems, such as punch-outs and delamination
- "Green" steel pavements
  - Much less distress development
  - Some diagonal cracking, probably due to local base failures

Slide 44

Preventive Rehabilitation Techniques

- Intensive concrete "super" patching
- AC overlays of various thickness
- PCC bonded thin asphalt overlays
- Impermeable membranes + AC overlays
- Rubblize + AC overlay

Results:

- *Thin asphalt overlays were the most successful and are recommended as preferred rehabilitation strategy*

Slide 45

Preventive Maintenance Techniques

- Cathodic Protection of Rebar mat
- Use of corrosion inhibitors in deicing salt

Results:

Both methods were ineffective in reducing distress

Slide 46

Summary

1. All eight State DOT's use Preventive Maintenance
2. PMS Data is useful in defining needs
3. None of the States currently have History of observations to prove PM value
4. PMS follow-up data – Annual Condition and Roughness – can be useful
5. State DOTs are urged to record all data in their PMS for analysis

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Slide 47

Module 8 - Objectives

Can you define the role that PMS data have played in:

- Development and implementation of Preventive Maintenance programs, and
- Tracking the performance of Preventive Maintenance projects?

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MODULE 9

Pavement Preservation Strategies

Module 9

Pavement Preservation Strategies (Including LCCA)

Instructional Time: 65 minutes

Participant Questions

1. What preservation strategies does your agency use?
2. When do you use Life Cycle Cost Analysis, and when do you just apply standard preservation treatments?
3. What improvements would you like to make?

Slide 1

Module 9: Pavement Preservation Strategies

- Preservation/Rehabilitation Overview
- Examples of engineering analysis in:
  - Pennsylvania State DOT
  - Montana State DOT
- All made possible by PMS data

11/15/2002 Module 9 1

Slide 2

Module 9 - Objectives

- Define concepts of Preservation
- Define concepts of Rehabilitation
- Recognize interface of these and Preventive Maintenance
- Illustrate concepts in PENNDOT and Montana DOT

11/15/2002 Module 9 2

Slide 3

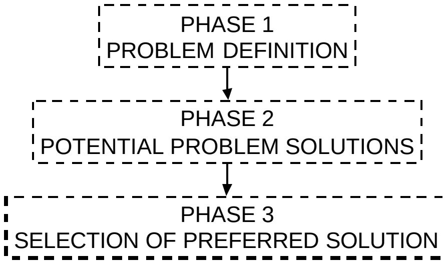
Preservation & Rehabilitation

- Emphasis shifting from new facilities to maintenance and rehabilitation
- When routine maintenance no longer cost-effective, rehabilitation required
- Array of options make rehabilitation design a complex process
- Considerable amount of analysis and engineering judgement required
- Documented performance histories in PMS database improve design process

11/15/2002 Module 9 3

Slide 4

1986 AASHTO Guide Structure for Rehabilitation Design



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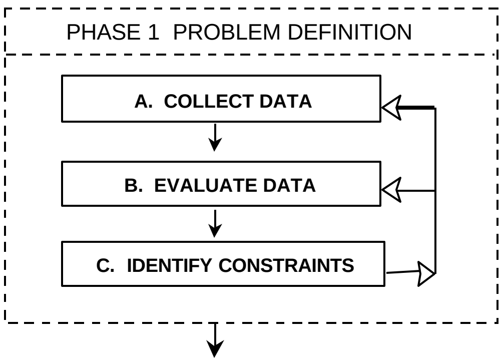

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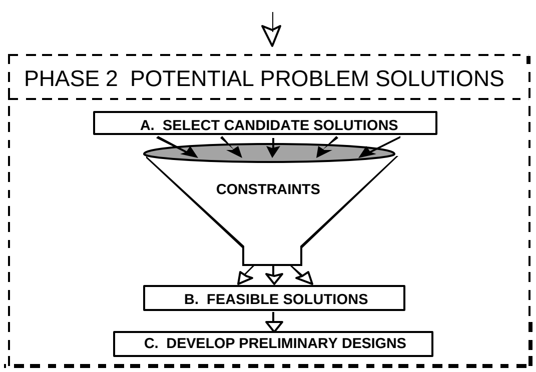


Slide 7

PHASE 3. SELECTION OF PREFERRED SOLUTION

A. COST ANALYSIS

↓

B. NON-MONETARY CONSIDERATIONS

↓

C. PREFERRED REHABILITATION ALTERNATIVE

↓

D. DETAILED DESIGN

11/15/2002 Module 9 7

Slide 8

Non-overlay Methods

1. Full depth repair
2. Partial depth patching
3. Joint and crack sealing
4. Subsealing and undersealing
5. Grinding and milling
6. Sub-drains
7. Pressure relief joints
8. Load transfer restoration
9. Surface treatments

11/15/2002 Module 9 8

Slide 9

Data Collection for Rehab Design Evaluation

1. Delineation of analysis units
2. Drainage evaluation
3. Pavement distress survey
4. Nondestructive testing
5. Field sampling and testing

11/15/2002 Module 9 9

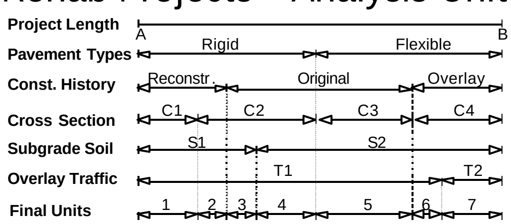
Slide 10

Analysis Units

1. Pavement type
2. Construction history
3. Pavement structural characteristics
4. Subgrade soil type
5. Traffic
6. Pavement condition

Slide 11

Rehab Projects - Analysis Units

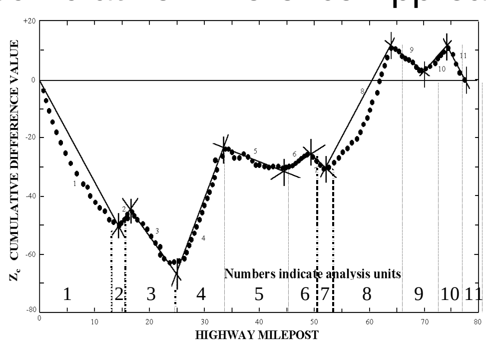


Unit Attributes:

Unit Number	1	2	3	4	5	6	7
Pavement Type	R	R	R	R	F	F	F
Construction Hist.	REC-5	REC-5	OR-15	OR-15	OR-15	OL-20	OL-20
Cross Section	C1	C1	C2	C2	C3	C4	C4
Subgrade	S1	S1	S1	S2	S2	S2	S2
Overlay Traffic	T1	T1	T1	T1	T1	T1	T2

Slide 12

Cumulative Difference Approach



Slide 13

AASHTO Performance Models

- Restoration Performance Models
  - Mostly for rigid pavements
- Overlay Performance Models
  - Mostly for flexible pavements

Slide 14

Summary

- Project evaluation
  - PMS data for location/condition
  - Additional investigation
  - Deflection testing
  - Field samples
- Performance models

Slide 15

PennDOT - Selecting Concrete Pavement Rehabilitation Strategies

Slide 16

Case Studies for Concrete Pavements

I. Concrete pavement restoration (CPR) of Jointed Concrete Pavement, six projects on I 79, I 80 and I 83, Mercer and York County

II. Rubblization existing concrete pavement with concrete overlay, I 80, Mercer County

Slide 17

PMS Data for Both Evaluated Projects

- Pavement distress and condition history
- Pavement construction history
- Understanding of design history
- Material used and existing condition
- Construction methods
- Traffic history
- Climatic history (at least in general)
- Subgrade type, characteristics, behavior
- Drainage (design and effectiveness)

Slide 18

Normal CPR activities

- Correcting deficiencies in existing pavements
- Can include
  - Major patching, joint rehab
  - Undersealing
  - Spall repair
  - Drainage improvement
  - Tied concrete shoulders
  - Diamond grinding

Slide 19

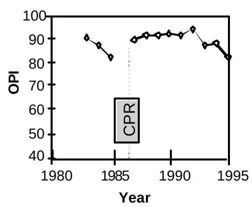
CPR in Case Study I

- Joint rehabilitation @ 18.5 m (61.5’) centers
- PCC spall repair, mainly at cracks
- Diamond grinding of bumps
- Tied concrete shoulders added
- Six CPR-Projects carried out between 1984 - 1986

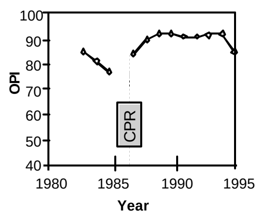
Slide 20

Performance of 6 CPR Projects

Interstate 79, SB, Mercer Co.
CPR 1986, No resurface



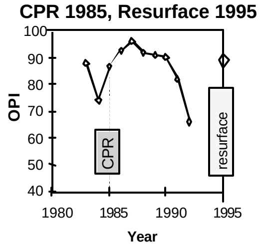
Interstate 79, NB, Mercer Co.
CPR 1986, No resurface



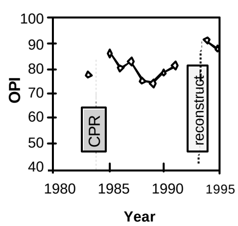
Slide 21

Performance of 6 CPR Projects (continued)

Interstate 79-NB, Butler Co.
CPR 1985, Resurface 1995



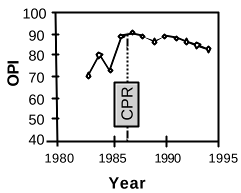
Interstate 80, WB, CPR 1984
Reconstruction 1993



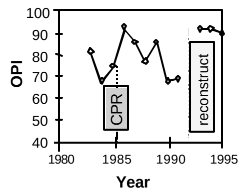
Slide 22

Performance of 6 CPR Projects (continued)

Interstate 83, NB, York Co.
CPR1986, No resurface



Interstate 80, NB, Mercer Co.
CPR1985, Reconst. 1992



Slide 23

Case Study II Rubblization and Concrete Overlay

- Project carried out in 1986-87
- Length of project 8 km (5 miles)
- Part of Interstate 80 in Mercer County

Slide 24

History - Case Study II

- Concrete pavements constructed in late 1950's
- Poor subgrade and high traffic loadings
- Late 1970's & early 1980's 75 km (47 miles) of various rehabs
  - 48 km (30 miles) of (partial) rubblization with unbonded CRCP overlay (unsuccessful)
  - 19 km (12 miles) of crack and seating with 330 mm (13") AC overlay (unsuccessful)
  - 8 km (5 miles) with straight 254 mm (10.5") AC overlay (this project)

Slide 25

Problems with AC overlaid Concrete Pavement

- Poor subgrade support
- Did not place .3 to .6 m (1 to 2 ft) granular blanket called for in original design
- 18.5 m (60.7 ft) joint spacing
- Severe stripping and damage of reflective cracks in AC above joints, resulting in depressions

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Construction Details Case Study II

- Removed 267 mm (10.5") asphalt overlay
- Rubblized existing concrete into much smaller fragments than with earlier tried cracking and seating
- 305 mm (12") Jointed concrete overlay
- 6.1 m (20') Skewed joint and tied shoulder
- New pavement drains

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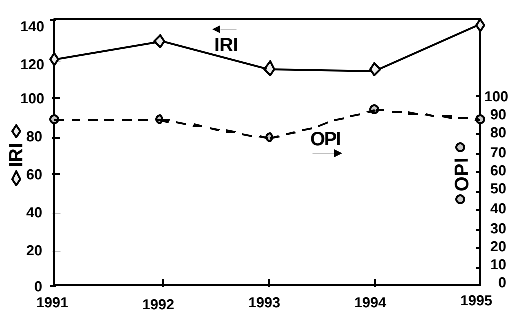
Performance of Rehab of Case II



Slide 28

Key to Success of CPR
(Concrete Pavement Restoration)

- Pavement is basically sound
- OPI > 70 (Overall Performance Index)
- Proper evaluation of pavement condition and history using PMS
- Knowledge of performance of previous CPR's

Slide 29

Conclusions

- Concrete Pavement Restoration can sometimes (not always) increase service life of pavement as long as structurally sound prior to restoration
- For concrete pavement with structural failures a thorough rubblization & effective seating of existing pavement with 305 mm (12") concrete overlay, 6.1 m (20') skewed joints and tied shoulders has so far provided good solution.

Slide 30

Montana State DOT's Engineering Analysis Elements

- Module 9:
  - Overview of MDT PMS
  - Optimize preservation through LCCA of various alternatives
- Module 10:
  - Integration of Maintenance in MDT's PMS

Slide 31

Background on MDT

(Montana Department of Transportation)

- Montana is the fourth largest state
- Total population about 800,000
- Billings is the largest metropolitan area (population 75,000)
- Roadway network over 54,400 km (34,000 miles)
- MDT is responsible for approximately 38,400 km (24,000 lane miles)

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Slide 32

MDT Organization

- Five districts
- Eleven maintenance divisions
- PMS section is responsible for all NHS, state and local federal-aid roadways

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Slide 33

PMS Overview

- Data Collection and Management
  - Inventory
  - History
  - Condition
  - Traffic
- Pavement Management Analyses
- PMS Update/Feedback Process

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Condition Survey

- 60 m (200 ft) sample of visual distress, taken at every milepoint using a walking survey
- Sections are easy to locate in the field and remain consistent from year to year
- Network sampling once per mile to estimate condition of the network
- Condition surveys are recorded & stored in the database on a per mile basis

Slide 35

Deflection Testing

- Network-level structural rating is performed by routine deflection testing using a Road Rater
- Network-wide structural information is used to help identify structural problems early
- Assigned minor rehabilitation and maintenance treatments may be adjusted to extend the life of the pavement before major rehabilitation or reconstruction is required based on deflection measurements

Slide 36

Traffic Information

PMS stores traffic information containing:

- AADT
- ESAL estimates on the network
- Used for network and project level analysis
- Traffic counts, classifications, and truck weight information collected by the Traffic Division and stored in central Oracle database

Slide 37

Database System

- Entire pavement management database resides on centralized relational database system using Oracle 7.2
- PMS has client/server configuration, ideal for maintaining single, well controlled database that all users can access
- PMS also vehicle to allow effective coordination and integration among different sections at MDT
- PMS analysis software resides on networked microcomputers, no downloading required.

Slide 38

Database System (Cont.)

- PMS Section responsible for maintaining most of PMS related data.
- Specific data tables may be maintained by other sections within Department.
- Coordination between PMS Section and other Sections provides strong incentive for good communication.
  - (e.g., traffic information & contract work data is maintained by other groups within MDT).
- Information Services Bureau is coordinator & overall database administrator.

Slide 39

Pavement Management Analyses

- Pavement Condition Analysis
- Remaining Service Life
- Pavement Performance
- Investment Analysis
- Project Selection

Slide 40

Pavement Condition Analysis

- Condition indices based upon individual distresses or any combination, they include:
  - Roughness
  - Fatigue cracking
  - Environmental cracking
  - Rutting
  - Structural index
  - Safety index
  - Combined roughness and cracking
  - Overall pavement index
- Indices essential for remaining service life analysis, decision trees, multi-year prioritization and optimization, etc.

Slide 41

Pavement Performance Models

- Pavement performance models required for network level analysis
- Structure of models dependent on type of network level analysis being used
- Deterministic models used for estimating remaining service life, project selection, treatments assignment and prioritizing projects over multi-year period
- Models also used for risk based life-cycle cost analysis system

Slide 42

Inputs for LCCA (Life-Cycle Cost Analysis)

- Pavement performance inputs
  - measured or estimated as needed
- Cost inputs
  - define magnitude of costs for each action
- Project inventory
  - defines location, size, traffic, environment and other parameters that are independent of alternative treatments

Slide 43

Obtaining Pavement Performance Inputs

- Currently enough data available to estimate mean lives of various "typical" treatments in database
- However variability estimates often difficult to make because of low number of data points for treatments. Additional engineering judgement used to estimate variability in treatment lives

Slide 44

Obtaining Cost Inputs

- Cost inputs retrieved from selected projects similar to project being studied
- Cost inputs also retrieved from contract administration files and bid lists for unit costs
- Composite estimates of treatment costs estimated from the collected data

Slide 45

Example with 2 Alternative Rehabilitation Strategies

Project length 9.3 km (5.8 mi), width 9.6 m (32 ft), Design Life 30 yrs

Yr	Strategy 1	Strategy 2
0	**Thin Resurfacing (4yrs)**	**Reconstruction (20 yrs)**
4	**Thin Resurfacing (4yrs)**	
8	**Reconstruction (20 yrs)**	
20		**Thick Overlay (15 yrs)**
28	**Thin Resurfacing (4yrs)**	

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Treatment Costs

Cost in '000 $

Treatment	Construct Cost	Administr. Cost	Maintenance Cost	User Delay Cost**
Thin Resurfacing Design Life 4 yrs	1,200	250	----	99.5
Reconstruction Design Life 20 yrs	2,400	350	----	199.0
Crack Seal *(Years 3,10,17)*			*11.0*	*6.6*
Seal and Cover *(Years 7, 14)*		*40.0*	*200.0*	*11.1*
Thick Overlay Design Life 15 yrs	1,800	350	----	132.7
Crack Seal *(Years 3, 9, 13)*			*11.0*	*6.6*
Seal and Cover *(Years 6, 11)*		*40.0*	*200.0*	*11.1*

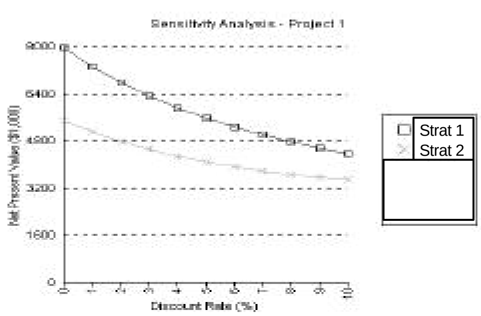
Slide 47

Simulation Life Cycle Cost Analysis Results

Alternative	Net Present Value	Standard Deviation	Minimum Likely Value	Maximum Likely Value
1. (3Thin Surf+Rec)	$4,677,955	$302,302	$4,085,443	$5,270,467
2. (Rec.+Thick Ovl)	$3,669,242	$168,943	$3,338,114	$4,000,370
Difference (1-2)	$1,008,713	$133,359		

Slide 48

Sensitivity of Discount Rate



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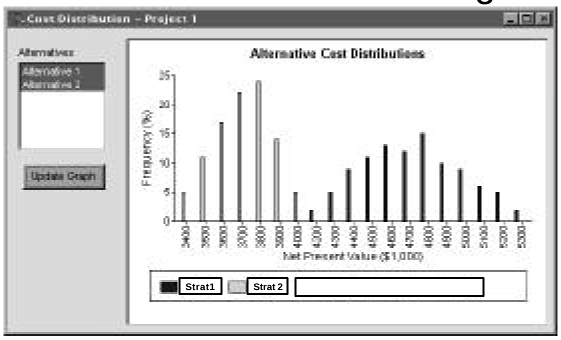
Cost Distributions of Strategies



Slide 50

Results of LCCA

Strategy 2 is clearly the better alternative in this example

- Mean (expected) life cycle cost smaller than for Strategy1
- Variability for Strategy 2 less, so this alternative less "risky"
- Sensitivity of Strategy 2 to discount rate (which is uncontrollable) also lower

Slide 51

Conclusions

- Risk based life-cycle cost methodology and corresponding Visual LCCA software form effective tool for LCCA
- The analysis would be cumbersome without the availability of a reliable and comprehensive PMS Database

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Module 9 - Objectives

Can you now:

- Define concepts of Preservation?
- Define concepts of Rehabilitation?
- Recognize interface of these with Preventive Maintenance?

MODULE 10

Pavement Maintenance Effect on Performance

Module 10

Pavement Maintenance Effect on Performance

Instructional Time: 60 minutes

Participant Questions

1. Are maintenance activities recorded in your PMS?
2. Does your agency have a Maintenance Management System?
3. If so, how is MMS linked to PMS?

Slide 1

Module 10: Pavement Maintenance Effect on Performance

- Overview of Maintenance Systems
- Maintenance Management Overview
- Examples of engineering analysis in Montana State DOT

Slide 2

Objectives of Module 10

- Show relation of maintenance elements & PMS
- Outline concepts of MMS
- Summarize various aspects of maintenance
- Apply engineering analysis to maintenance

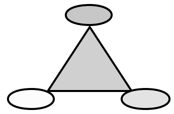
Slide 3

Overview of Maintenance Concepts

- Definition of maintenance varies by agency
- Maintenance and rehab are closely related
- Many agencies separate the two by budget definitions

Slide 4

Maintenance Policy Factors



- Funds available
- Historical precedent
- Political and Organizational considerations

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Slide 5

Funds Available

- Available funds usually applied to fill most extreme/most expensive needs
- Remaining budget then proves inadequate to serve total area involved
- Consequently routine maintenance suffers, leading to downward cycle of deterioration
- Cycle prevented by budgeting for maintenance as part of pavement management

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Slide 6

Historical Precedent

- Until recently maintenance not widely researched
- As a result many maintenance methods adopted without proof of their general applicability or effectiveness
- Highway system not a homogeneous entity, e.g. Interstates construction ‘54-’60 with subsequent high-quality maintenance, originally at low cost. By mid-’70 very costly

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Slide 7

Political and Organizational Considerations

- In difficult financial times maintenance often sacrificed
- In case of unusual event (extreme winter), budget often substantially reduced
- Two hurdles for integrating management in central office with decentralized maintenance operations in the field:
  - Time delay between planning and execution
  - Different location and culture

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Slide 8

Policy Variations

- Inadequate funds result in local field manager personal preference choice in spite of policy
- Routine maintenance gets preference over preventive maintenance
- Visible condition such as mowing and trash pick-up get served first

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Slide 9

Analysis of Effects of Policy Changes

Use PMS data to:

- Analyze effect of budget changes on highway system (network level)
- Reanalyze any given pavement due to delays from budget changes (project level) and identify possible alternative actions

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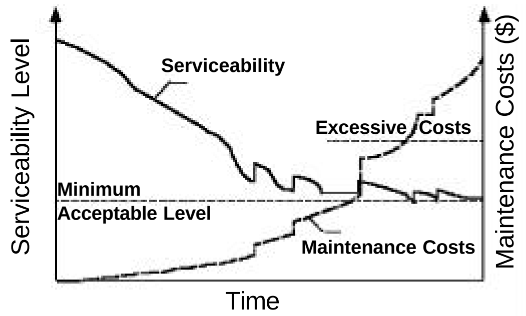
Slide 10

Unacceptable Maintenance Costs



Slide 11

Evaluation Decision Criteria

- Single distress or performance index
  - Threshold levels often act as trigger values for required maintenance action
- Combination index
  - Useful for overall analysis and ranking at network level,
  - Limited use for maintenance

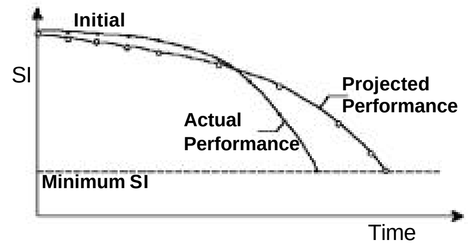
Slide 12

Feedback to PMS

- Programming, planning and execution of maintenance activities
- Evaluation of maintenance models

Slide 13

Projected/Observed Performance



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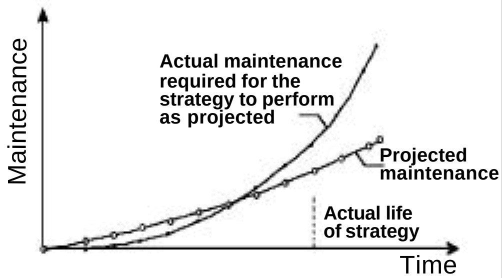
Projected/Observed Maintenance History



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Slide 15

Problems with Current Maintenance Data

- Actual maintenance performed can be difficult to assess
- Records often “generalized" to average values rather than actual work on a bad section
- Costs of maintenance performed even more difficult to obtain, particularly for small portions of a section

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Slide 16

Maintenance Summary

- Maintenance can significantly influence pavement performance
- Proper maintenance management essential for effectiveness & efficiency
- Maintenance policies, costs, economics & decision criteria play major role
- Much needed compatibility with pavement management systems requires further efforts

Slide 17

The Importance of Maintenance Transcends PMS alone

- There are many operating details that should be dealt with
- This is done through a Maintenance Management System (MMS)

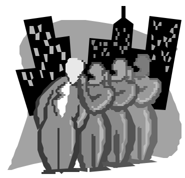
Slide 18

MMS deals with other factors in addition to Pavements

- Right of Ways
- Bridges
- Signs, markings
- Drainage structures
- Equipment
- Materials
- Etc.

Slide 19

Maintenance Management Systems have Close Ties to PMS



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Slide 20

MMS Objectives

- Plan, direct, and control maintenance activities in order to achieve acceptable level of service (LoS)
- Evaluate methods and materials so that economical & efficient practices are developed
- Acquire and report maintenance cost data so that realistic unit costs for specific sections may be determined

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Slide 21

Purpose of MMS

- Exercise control over budget and maintenance program
- Quantify maintenance needs
- Identify resources to meet those needs
- Determine Standards and Set Priorities
- Plan and manage work
- Monitor Performance

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Slide 22

MMS Modules

- Network Analysis – Planning & Budgeting
- Work Management – Daily/Weekly Schedules
- Contracted Maintenance
- Labor Management
- Equipment Management
- Materials Inventory Management
- System Administration

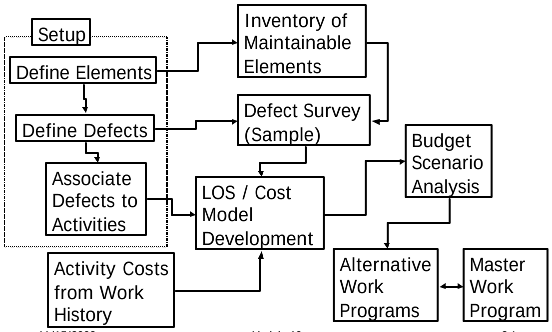
Slide 23

Analysis Module

- Maintenance Rating Program
  - Inventory
  - Defects
- Level of Service assessment
- Work Plan Development
- Budgeting
- Tracking Expenditures

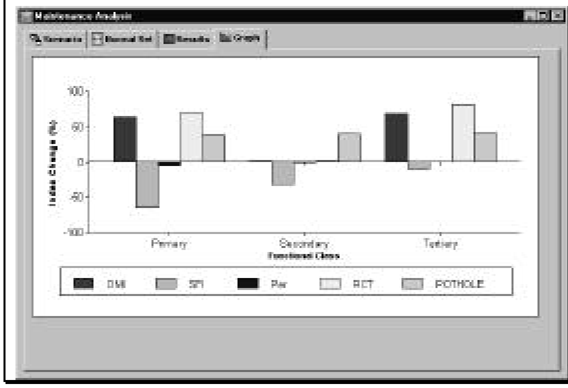
Slide 24

Level of Service Analysis



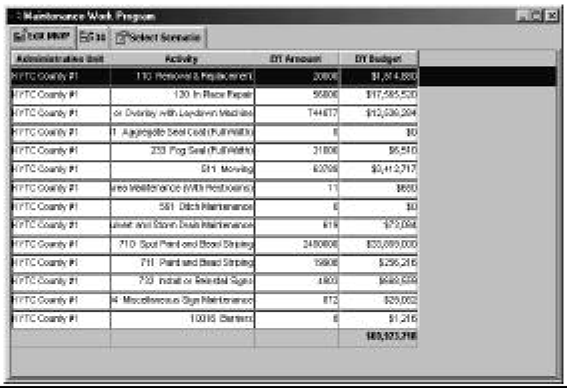
Slide 25

Predicted Network Condition



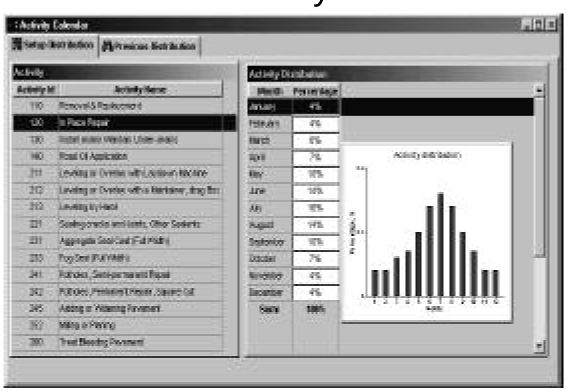
Slide 26

Annual Work Program



Slide 27

Seasonal Activity Calendar



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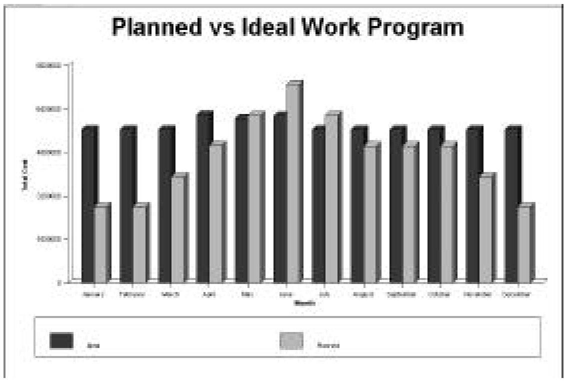
Work Program Comparison



Slide 29

Work Management Module

- Daily/Weekly Work Planning
  - Labor, Materials and Equipment
  - Work activity and location
- Work Accomplishment

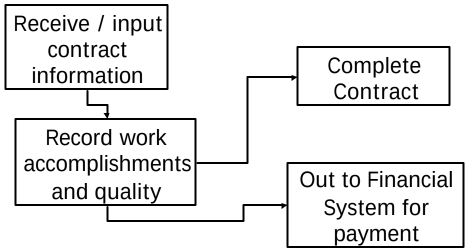
Slide 30

Contracts Module

- Plan contract details
- Monitor Contract Work
- Comparison of Contract vs. State Forces work

Slide 31

Maintenance Contracts



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Slide 32

Labor Module

- Employees
- Crews - Foremen
- Assignments
  - Work
  - Overhead
  - Leave or Vacations

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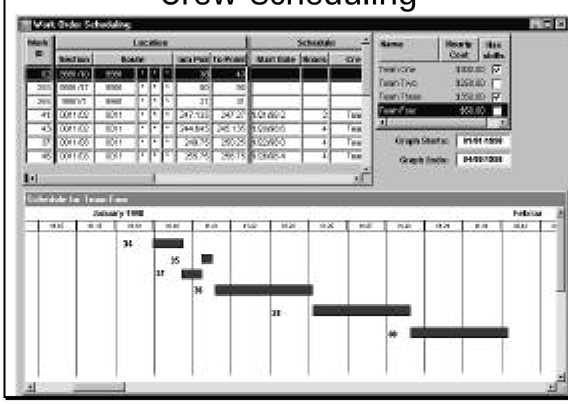
Slide 33

Crew Scheduling



Slide 34

Equipment Module

- Fleet and Heavy Equipment
  - Vehicle (equipment) Inventory
  - Repair (in-house or others)
  - Spare parts warehouse
  - Fueling
  - Leasing
  - Fleet Management

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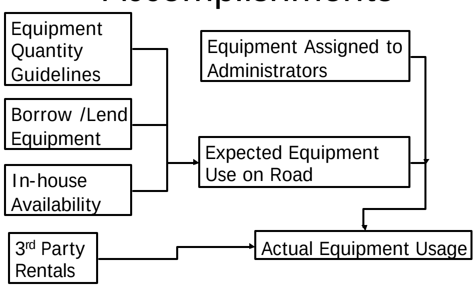
Equipment Planning & Accomplishments



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Materials Module

- Stockpiles at Maintenance facilities and warehouses
- Materials Management
- Use on Projects

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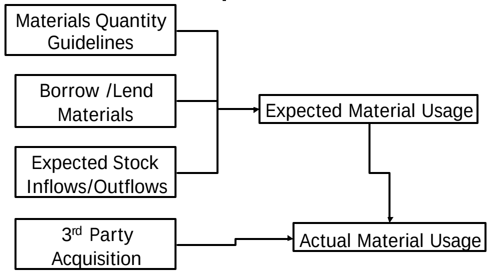
Material Planning & Accomplishments



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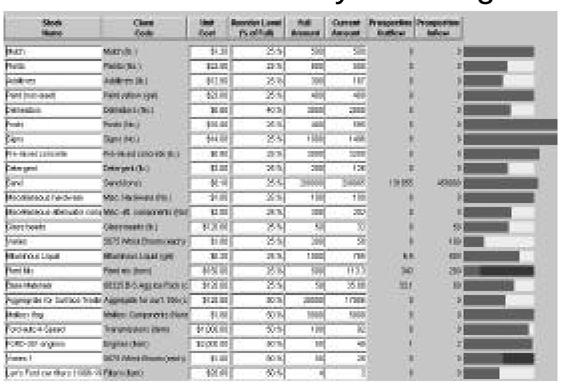
Materials Inventory Tracking



Slide 39

Montana's PMS

- In 1996 – Montana decided to include maintenance as a key part of PMS
- This section covers Montana's related activities

Slide 40

Integration of Maintenance in Montana's PMS

- Why look at maintenance
- Understanding maintenance effectiveness
- Effects of maintenance on performance

Slide 41

Why Look at Maintenance

- Many miles in Montana are low volume and rank low in rehabilitation programs
- Consequently maintenance division spends large part of budget on these roads to keep them in serviceable condition

Slide 42

Maintenance History

- At one point, maintenance budget extremely low at $2 million per year providing inadequate maintenance levels
- Maintenance division applied systematic procedures to improve reporting and understanding of maintenance information
- Consequently, additional biennial budget of $13 million per year made available

Slide 43

Keys for Maintenance Program Success

- Adequate recognition of maintenance division
- Systematic analytical processes applied based on high quality information
- High quality of maintenance materials and workmanship
- Room for research and technology innovation in improving overall maintenance process
- Tight integration with PMS, a goal of MDT

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Evaluating Maintenance

- MDT evaluates & records effectiveness of:
  - crack sealing
  - fog sealing
  - chip seals
  - thin overlays
  - non-pavement activities
- Maintenance reports used to update PMS construction records
- Main purpose of evaluation to obtain data for upgrading performance models

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Maintenance Data Recording

- Details of maintenance work recorded in PMS:
  - location (to the 0.1 mile)
  - application details: equipment, quantities, materials, rates and thickness, etc
  - weather conditions
  - name of contractor or maintenance unit
- New MMS being developed, this will automate data transfer to PMS history file

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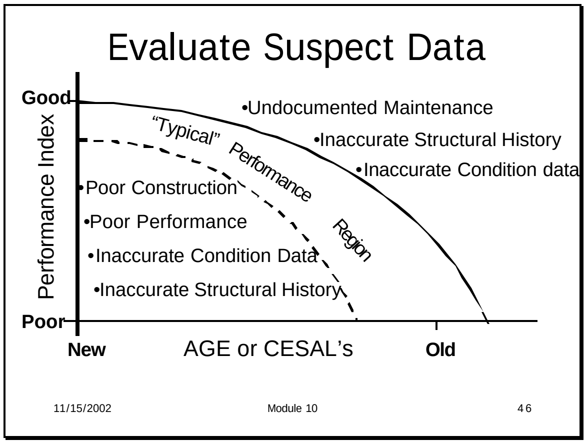

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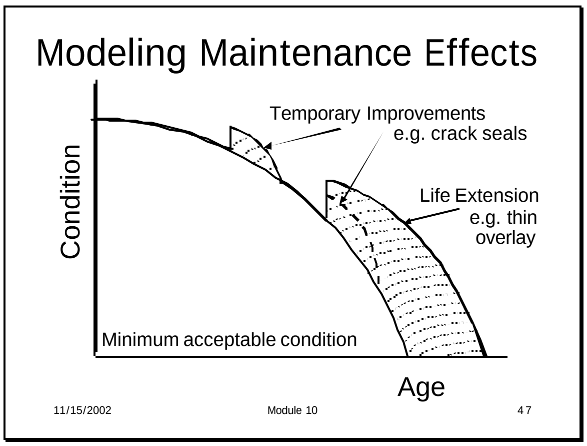

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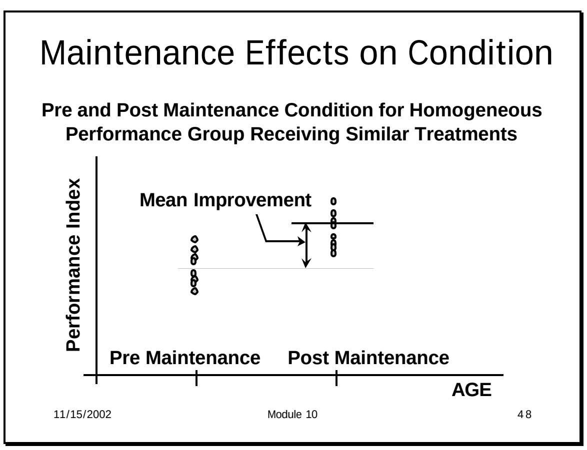

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Maintenance Effects on Deterioration

- Undocumented maintenance has "flattening" effect on performance curves
- Records of maintenance activities can be used to delineate performance groups
  - Identification of maintenance policies across varying pavement types
  - Recording of actual maintenance performed

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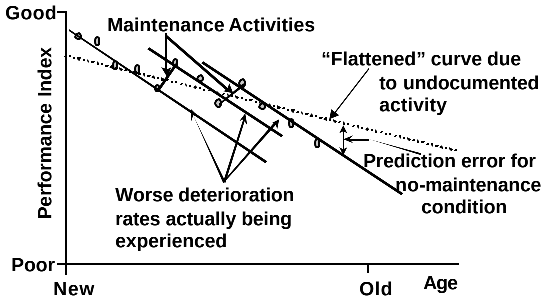
Undocumented Maintenance Effects On Deterioration Curves



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Conclusions

- Maintenance activities can have major effect on:
  - pavement condition
  - rate of deterioration
  - pavement life
- A properly executed MMS can quantify these effects
- Full benefits occur when MMS and PMS are integrated as in Montana.

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Objectives of Module 10

- Are maintenance activities recorded in your PMS?
- Does your agency have a MMS?
- If so, is it linked to PMS

Glossary

GLOSSARY OF TERMS

AADT
The average 24-hour traffic volume counts collected over a number of days greater than 1 but less than a year, at a given location. AADT can also be approximated by adjusting the ADT count for daily (weekday versus weekend) and seasonal (summer versus winter) variations.

AASHTO
American Association of State Highway and Transportation Officials

ADT
The average 24-hour traffic volume counts collected over a number of days greater than 1 but less than a year, at a given location.

ADTT
The average 24-hour truck traffic volume counts collected over a number of days greater than 1 but less than a year, at a given location. ADTT may be expressed as a percentage of ADT.

Algorithm
A prescribed set of well-defined rules or processes for the solution of a problem in a finite number of steps.

Annual Costs
Any costs associated with the annual maintenance and repair of the facility.

Asphalt Emulsion Mix
A mixture of emulsified asphalt materials and mineral aggregate usually prepared in a conventional hot-mix plant or drum mixer at a temperature of not more than 127 °C (260 °F). It is spread and compacted at the job site at a temperature above 93 °C (200 °F).

Benefit-Cost Ratio
The ratio of the dollars of discounted benefits achievable to the given outlay of discounted costs.

Cape Seal
A surface treatment that involves the application of a slurry seal to a newly-constructed surface treatment or chip seal. Cape seals are used to provide a dense, waterproof surface with improved skid resistance.

Capital Costs
Non-recurring or infrequently recurring costs of long-term assets (including depreciation and property taxes).

CESAL

Cumulative Equivalent Standard Axle Loads, e.g. the summation of ESALs over a year (see ESAL).

Chip Seal
A surface treatment in which a pavement surface is sprayed with asphalt (generally emulsified) and then immediately covered with aggregate and rolled. Chip seals are used primarily to seal the surface of a pavement with non load-associated cracks and to improve surface friction, although they also are commonly used as a wearing course on low-volume roads.

Cold In-Place Recycling (CIR)
A process in which a portion of an existing bituminous pavement is pulverized or milled, the reclaimed material is mixed with new binder and virgin materials, and the resultant blend is placed as a base for a subsequent overlay. Emulsified asphalt is especially suited for cold in-place recycling. Although not necessarily required, a softening agent may be used along with the emulsified asphalt.

Cold Milling
A process of removing pavement material from the surface of the pavement either to prepare the surface (by removing rutting and surface irregularities) to receive overlays, to restore pavement cross slopes and profile, or even to re-establish the pavement's surface friction characteristics.

Combined Performance Indexes
Combinations of PI's, examples are Structural Index (STI), Surface Distress Index (SDI), Safety Index (SFI), Overall Pavement Index (OPI), Present Serviceability Index (PSI).

Crack Filling
A maintenance procedure that involves placement of materials into non-working cracks to substantially reduce infiltration of water and to reinforce the adjacent pavement. Working cracks are defined as those that experience significant horizontal movements, generally greater than about 2 mm (0.1 in). Crack filling should be distinguished from crack sealing.

Crack Sealing
A maintenance procedure that involves placement of specialized materials, either above or into working cracks, using unique configurations to reduce the intrusion of incompressibles into the crack and to prevent intrusion of water into the underlying pavement layers. Working cracks are defined as those that experience significant horizontal movements, generally greater than about 2 mm (0.1 in).

CRCP
Continuously Reinforced (Cement) Concrete Pavement

Data Mining
Reviewing existing data, data bases and subsets of data, to determine what information might be available that had previously been overlooked.

Default Value
A design value that is based on experience or on studied conclusions and that is used as a substitute value when an actual value is not available.

Dense-Graded Asphalt Overlay
An overlay course consisting of a mix of asphalt cement and a well-graded (also called dense-graded) aggregate. A well-graded aggregate is uniformly distributed throughout the full range of sieve sizes.

Deterministic Model
A model that expresses the interaction of system elements with complete certainty, that is, as absolute values.

Diamond Grinding
A maintenance procedure for concrete pavements that involves the removal of a thin layer of concrete (generally no more than 6.4 mm [0.25 in]) from the surface of the pavement to remove surface irregularities (most commonly joint faulting), to restore a smooth riding surface, and to increase pavement surface friction.

Diamond Grooving
The establishment of discrete grooves in the concrete pavement surface using diamond saw blades to provide a drainage channel for water and thereby reduce the potential for hydroplaning and wet weather accidents.

Discount Rate
In cost-benefit analysis, an interest rate used to reduce the value of benefits or costs accruing in future years back to their current worth (present value). If the discount rate is 4 percent, $1.04 a year from now is of equal value as $1.00 today.

Empirical Model – Prediction based on experience only.

Emulsified Asphalt
An emulsion of asphalt cement and water, which contains a small amount of an emulsifying agent. Emulsified asphalt droplets, which are suspended in water, may be either the anionic (negative charge) or cationic (positive charge) type, depending upon the emulsifying agent.

ESAL
Equivalent Standard Axle Load, used to transform loads by different vehicles into standard units.

Equivalent Uniform Annual Cost (EUAC)
The net present value of all discounted cost and benefits of an alternative as if they were to occur uniformly throughout the analysis period. Net Present Value (NPV) is the discounted monetary value of expected benefits (i.e., benefits minus costs).

FHWA
Federal Highway Authority

Fog Seal
A light application of slow setting asphalt emulsion diluted with water. It is used to renew old asphalt surfaces and to seal small cracks and surface voids.

FWD

Falling Weight Deflectometer, used to assess the structural pavement properties.

GIS
Geographic Information System

Heater Scarification
A form of Hot In-Place Recycling in which the surface of the old pavement is heated, scarified with a set of scarifying teeth, mixed with a recycling agent, and then leveled and compacted.

Hot In-Place Recycling (HIR)
A process which consists of softening the existing asphalt surface with heat, mechanically removing the surface material, mixing the material with a recycling agent, adding (if required) virgin asphalt or aggregate to the material, and then replacing the material back on the pavement.

Hot Mix Asphalt (HMA)
High quality, thoroughly controlled hot mixture of asphalt cement and well-graded, high-quality aggregate thoroughly compacted into a uniform dense mass.

Hot Surface Recycling
See hot in-place recycling.

Inflation rate
The rate of increase in the general price levels, caused usually by an increase in the volume of money and credit relative to available goods. The inflation rate is also reflective of the rate of decline in the general purchasing power of a currency.

Initial Costs
All costs associated with the initial design and construction of a facility, placement of a treatment, or any other activity with a cost component.

International Roughness Index (IRI)
A ratio of the accumulated suspension motion to the distance traveled obtained from a mathematical model of a standard quarter car transversing a measured profile at a speed of 80 km/h (50 mph). Expressed in units of meters per kilometer (inches per mile), the IRI summarizes the longitudinal surface profile in the wheelpath.

JCP
Jointed (Cement) Concrete Pavement.

Joint Resealing
The resealing of transverse joints in concrete pavements to minimize the infiltration of surface water into the underlying pavement structure and to prevent the intrusion of incompressibles into the joint.

Joint Sealant Reservoir
The channel sawed or formed at a joint that accommodates the joint sealant.

Level of Service
A qualitative rating of the effectiveness of a highway or highway facility in serving traffic (users), in terms of operating conditions (volume, speed, comfort, safety).

Load Transfer Restoration (LTR)
The placement of load transfer devices across joints or cracks in an existing jointed PCC pavement. LTR is used on existing jointed PCC pavements that were constructed without dowel bars at transverse joints.

Life Cycle Cost Analysis (LCCA)
An economic assessment of an item, system, or facility and competing design alternatives considering all significant costs of ownership over the economic life, expressed in terms of equivalent dollars.

Maintenance Management System (MMS)
Rational procedures that provide optimum maintenance strategies for pavements and related elements like ROW, culverts, guardrails, signs, traffic lights, etc. These procedures are based on predicted maintenance effectiveness and cost for a desired Level Of Service, and the optimal employment of labor, equipment and materials, whilst incorporating feedback regarding the various attributes, criteria and constraints involved.

Mechanistic Model
Prediction based on known mechanistic properties of uniform materials, such as Youngs Modulus, strain and stress at break.

Microsurfacing
Microsurfacing is a mixture of polymer modified asphalt emulsion, mineral aggregate, mineral filler, water, and other additives, properly proportioned, mixed and spread on a paved surface.

Mineral Filler
A finely divided mineral product, at least 70 percent of which will pass a 0.075 mm (No. 200) sieve. Pulverized limestone is the most commonly manufactured filler, although other stone dust, hydrated lime, portland cement, and certain natural deposits of finely divided mineral matter are also used.

Model
A mathematical description of a real-life situation that uses data on past and present conditions to make a projection about the future.

Nominal Dollars
Dollars of purchasing power in which actual prices are stated, including inflation or deflation. Hence, nominal dollars are dollars whose purchasing power fluctuates over time.

NOVACHIP™
A maintenance treatment for AC pavements, sometimes called an ultrathin friction course: it consists of a layer of hot-mix material placed over a heavy, polymer modified emulsified asphalt tack coat; the total thickness of the application being typically between 10 and 20 mm (0.40 and

0.80 in). It can be used to reduce deterioration caused by weathering, raveling, and oxidation, and can be used to fill ruts and to smooth corrugations and other surface irregularities.

Open-Graded Friction Course (OGFC)
An overlay course consisting of a mix of asphalt cement and open-graded (also called uniformly-graded) aggregate. An open-graded aggregate consists of particles of predominantly a single size.

Overall Pavement Index (OPI)
A combination of various weighted pavement performance indices (e.g. ride, rutting, cracking, etc).

Partial-Depth Recycling
See cold in-place recycling.

Pavement Distress Index (PDI)
A combination of several distress ratings.

Pavement Evaluation
A technique to measure a range of pavement characteristics such as roughness, rutting, friction and various distresses such as cracking.

Pavement Management
A coordinated systematic process for carrying out all activities related to providing pavements.

Pavement Management Software
A set of tools to assist decision makers in preserving a pavement network.

Pavement Management Section
A location-defined part of the pavement network with a homogeneous cross section, uniform construction history, traffic loading characteristics and history, and uniform drainage and climatic conditions.

Pavement Management System (PMS)
A systematic process that collects and analyzes pavement information with rational procedures that provide optimum pavement strategies based on predicted pavement attributes incorporating feedback regarding the various attributes, criteria and constraints involved. PMS is also called PMIS (Pavement Management Information System) or RMS (Roadway Management System).

Pavement Performance Group
Grouping of pavement sections for performance models based on Traffic Levels (e.g. AADT), Functional Class (e.g. Interstates, State Highways, etc) and Road Structure Category (RSC)

Pavement Performance Model
An empirical or mathematical representation of predicted pavement performance and behavior.

Pavement Preservation
The sum of all activities undertaken to provide and maintain serviceable roadways; this includes corrective maintenance and preventive maintenance, as well as minor rehabilitation projects.

Pavement Preventive Maintenance
Planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retard future deterioration, and maintains or improves the functional condition of the system (without increasing the structural capacity).

Pavement Reconstruction
Construction of the equivalent of a new pavement structure which usually involves complete removal and replacement of the existing pavement structure including new and/or recycled materials.

Pavement Rehabilitation
Work undertaken to extend the service life of an existing pavement. This includes the restoration, placing an overlay, and/or other work required to return an existing roadway to a condition of structural and functional adequacy.

Pavement Serviceability Index (PSI)
A subjective rating of the pavement condition made by a group of individuals riding over the pavement.

Performance Index (PI)
A combination of weighted performance ratings taken from ride, rutting and other pavement evaluation data.

Periodic Costs
Costs associated with rehabilitation activities that must be applied periodically over the life of the facility.

Poisson's Ratio
The ratio of the reduced (increased) cross-section under tensile (compressive) stress, to the original cross-section. For an elastic material the ratio is 0.5.

Present Worth Method
Economic method that requires conversion of costs and benefits by discounting all present and future costs to a single point in time, usually at or around the time of the first expenditure.

Probabilistic Model
Quantification of a future condition using probabilities in an algorithm, where any one of several outputs, each of known probability, can occur for each alternative.

Quality Assurance (QA)
The systematic use of performance requirements, design criteria, specifications, production control procedures, and acceptance plans for materials, processes, or products to ensure prescribed properties or characteristics.

Quality Control (QC)
The system of collection, analysis, and interpretation of measurements and other data concerning prescribed characteristics of a material, process, or product, for determining the degree of conformance with specified requirements.

Real Dollars
Dollars of uniform purchasing power exclusive of general inflation or deflation. Real dollars have a constant purchasing power over time.

Recycling Agents
Organic materials with chemical and physical characteristics selected to address any binder deficiencies and to restore aged asphalt material to desired specifications.

Rejuvenating Agent
Similar to recycling agents in material composition, these products are added to existing aged or oxidized AC pavements in order to restore flexibility and retard cracking.

Retrofitted Load Transfer
See Load Transfer Restoration.

Road Structure Category (RSC)
Categorization of pavement structures based on surface material and thickness, underlying pavement structure, and rehabilitation type.

Rubberized Asphalt Chip Seal
A variation on conventional chip seals in which the asphalt binder is replaced with a blend of ground tire rubber (or latex rubber) and asphalt cement to enhance the elasticity and adhesion characteristics of the binder. Commonly used in conjunction with an overlay to retard reflection cracking.

Rubblization
Technique where existing concrete pavement is hammered into small pieces or chunks of loose material that will act as a granular base.

Salvage Value
The remaining worth of the pavement at the end of the analysis period. There are generally two components of salvage value: residual value – the net value from recycling the pavement and serviceable life – the remaining life of the pavement at the end of the analysis period.

Sand Seal
An application of asphalt material covered with fine aggregate. It may be used to improve the skid resistance of slippery pavements and to seal against air and water intrusion.

Seal Coat
See Chip Seal

Sandwich Seal
A surface treatment that consists of application of a large aggregate, followed by a spray of asphalt emulsion that is in turn covered with an application of smaller aggregate. Sandwich seals are used to seal the surface and improve skid resistance.

Scrub Seal

Application of a polymer modified asphalt to the pavement surface followed by the broom-scrubbing of the asphalt into cracks and voids, then the application of an even coat of sand or small aggregate, and finally a second brooming of the aggregate and asphalt mixture. This seal is then rolled with a pneumatic tire roller.

Shape Factor
The width to depth ratio of a joint sealant reservoir. A proper shape factor is required to allow the sealant to effectively withstand repeated extension and compression as the temperature and moisture in the slab changes. Most commonly available sealants require a shape factor between 1 and 2.

Slurry Seal
A mixture of slow-setting emulsified asphalt, well-graded fine aggregate, mineral filler, and water. It is used to fill cracks and seal areas of old pavements, to restore a uniform surface texture, to seal the surface to prevent moisture and air intrusion into the pavement, and to provide skid resistance.

Stiffness Modulus
Comparable to Youngs Modulus, but used for non-elastic materials. The Stiffness is defined as the ratio of applied stress to the resulting strain for a certain temperature and time of loading.

Stockpiled Cold Mix
An asphalt maintenance mix consisting of aggregate and emulsified asphalt, which once prepared can be stored and readily used for a period up to six months depending on the formulation of the emulsion used and the aggregate characteristics.

Stone Mastic Asphalt Overlay
An overlay course consisting of a mix of asphalt cement, stabilizer material, mineral filler, and gap-graded aggregate. A gap-graded aggregate is similar to an open-graded material but is not quite as open.

Surface Texture
he characteristics of the concrete pavement surface that contribute to both surface fiction and noise.

Undersealing
called sub-sealing, pressure grouting, or slab stabilization: this process consists of the pressure insertion of a flow able material beneath a PCC slab used to fill cavities beneath PCC slabs and occasionally to correct the vertical alignment by raising individual slabs.

User Costs
Costs incurred by highway users traveling on the facility and the excess costs incurred by those who cannot use the facility because of either agency or self-imposed detour requirements. User costs typically are comprised of vehicle operating costs (VOC), accident costs, and user delay costs.

Young’s Modulus or Elastic Modulus

The ratio of the stress (force per unit of surface area) to the resulting strain (relative increase in length) in a tensile test.